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"The Science of Railways," "The Romance of Gilbert Holmes,"

and "Primitive Carriers."

THE LOCOMOTIVE

ENGINE FAILURES

MOTIVE POWER DEPARTMENT

IN TWO BOOKS

BOOK I. THE LOCOMOTIVE—ENGINE FAILURES

BOOK II. THE MOTIVE POWER DEPARTMENT

THIS VOLUME EXPLAINS CONCISELY THE PRINCIPLES AND CONSTRUCTION OF THE LOCOMOTIVE AND GIVES PRACTICAL INSTRUCTIONS IN REGARD TO FAILURES AND BREAKDOWNS. IT DESCRIBES IN DETAIL THE MANNER IN WHICH THOSE CONNECTED WITH THE MOTIVE POWER DEPARTMENT OF A RAILROAD LOOK AFTER THE MAINTENANCE, REPAIR, DISTRIBUTION AND WORKING OF LOCOMOTIVES

THE WHOLE PROFUSELY EMBELLISHED AND ILLUSTRATED BY ENGRAVINGS PREPARED EXPRESSLY FOR THIS WORK

FORMING ONE OF THE SERIES OF VOLUMES COMPRISED IN THE REVISED AND ENLARGED EDITION OF

THE SCIENCE OF RAILWAYS

BY

MARSHALL M. KIRKMAN

EDITION 1910

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MOTIVE POWER.

DEDICATION.

This volume forms a part of THE SCIENCE OF RAILWAYS. It is embodied therein because the author knows of no good reason why engineers and firemen and others connected with the motive power department of railroads should not desire to know something about railroads generally, as well as others in the service. Certainly no body of men offers better material to select from in choosing the officers of railroads, provided they study the subject of railroading as a whole. The preparation of this volume occupied many years, and during that time the author submitted it for approval and revision to many men of eminent talent and great experience in connection with the specific subjects of which it treats. Indeed, throughout the preparation of this and other volumes embraced in THE SCIENCE OF RAILWAYS he actively sought the aid and advice of experts so that he might confidently offer to the reader something really useful and worthy of consideration. The engravings the work contains have for the most part

been prepared expressly for it, and are so complete that it is no exaggeration to say that nothing so extended has ever before been attempted in connection with any railway publication of this character, nor can more, it is believed, be desired by those studying the subject. In view of these facts, and because of the valuable aid and assistance the author has received, he begs to offer the work to railway men, and to respectfully dedicate it to them.

INTRODUCTION TO THE SCIENCE OF RAILWAYS.

I do not set out to write an exhaustive account of railway affairs, but rather to discuss those things which every railroad man may reasonably desire should form a part of his knowledge, if not of his experience. In the early history of railroads ignorance was general. This is no longer the case. Railway men now recognize that they must not only know thoroughly the particular work assigned them, but have more than a cursory knowledge of the duties of others. No man's experience is, in itself, wide enough to command this knowledge, and it is the object of this work, the result of nearly fifty years' practical experience and extended research, in some measure to supply.

The ancients believed the world ended where their vision ceased. Beyond was nothing; a void, simply. And so it is with ignorant men. They are insensible to the value of knowledge; to the accumulated experience of mankind. It lies beyond their vision or comprehension. Its invaluable treasures are to them as if they were not.

Not only this, but they resent knowledge in others. In the early history of railroads, books and treatises on the subject were angrily rejected by practical men, and the writers thereof held up to contumely. Fitness was based solely upon individual experience; upon the kaleidoscopic views of the needs of railroads which began and ended with particular persons. This is no longer the case. To-day knowledge in regard to railway operations is sought wherever it can be found. Men no longer rest content with their own experience. Books and treatises, which would in earlier days have been ridiculed or angrily resented as an impertinence, no longer irritate the egotistical nor excite outward expression of aversion upon the part of the obdurate and narrow-minded. Because of this spirit the railway world is ceasing to be a benighted region wherein men grope about in semi-darkness—the blind leading the blind. Its votaries are not only enlightened and tolerant, but anxious to avail themselves of the knowledge and experience of others. This spirit grows so rapidly that we may confidently look forward to the time when it will be everywhere recognized as necessary that railway men shall not only possess personal experience and skill, but also familiarity with the skill of others. Then an officer or employe, instead of being a

mere speck on the railway horizon, will be a center of light, familiar not only with his own department of work, but, in a general way, with the whole railway world. Thus his mind will be liberalized and his intelligence strengthened and deepened.

Railways are still in a state of evolution, and continue to take on each day the complexion of those who operate them. Every thing in which man is interested, like himself, advances or recedes. There is no stationary period. This is true of railroads. At this time they are on the upward plane. That which seems perfect to-day is bettered to-morrow. So that since the first edition of my books was issued I have labored unceasingly, not only to improve them, but to supply their shortcomings, until now the work is recognized by railway men as a library on the subject, having for its object the presentation of the underlying principles of all departments and the accepted practices that prevail therein. The object of such books is to present to railway men sources of information from which they may glean the facts that urge men in every department of human endeavor to achieve the highest results attainable and to provide them with easily accessible knowledge necessary in the performance of daily duties; for in such knowledge lie

advancement and ultimate success. The success of the railroad man of today cannot depend alone on physical capacity, integrity, sobriety and intelligence. To these must be added knowledge—a knowledge not only special, that is, of the work on which he is engaged, but general, that is, of his profession as a whole. Only those who have this larger knowledge are recognized as worthy of preferment or competent to administer departments or take executive position. This larger knowledge is impossible of attainment by those whose daily duties confine them within the narrow compass of routine toil, unless indeed they will study and avail themselves of the knowledge and experience of others.

As already stated, I have had (aside from my own practical experience of nearly fifty years) the advice and active assistance of men of the highest constructive and practical talent in the preparation of THE SCIENCE OF RAILWAYS, and so I trust and believe it will prove valuable to railway men who seek to enlarge their sphere of usefulness.

MARSHALL M. KIRKMAN.

BOOK I.

THE LOCOMOTIVE.

ENGINE FAILURES.

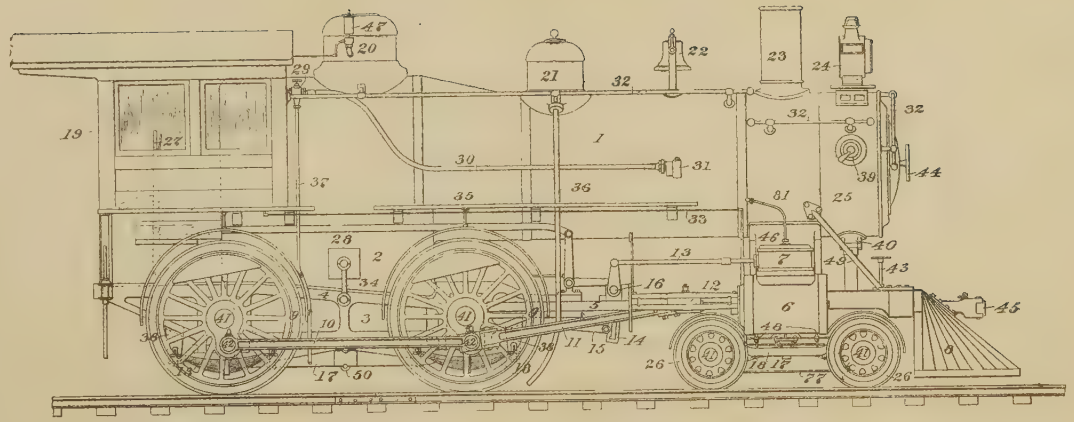
CHAPTER I.

DESCRIPTION OF THE LOCOMOTIVE.

The machinery of the locomotive is so vast and involved that its working and details can not be clearly explained in print, and to attempt it is to tire the reader and dull his enthusiasm without enlightening his understanding. The accompanying illustrations, however, will make plain what type is not able, unaided, to do. Great care has been taken to make these cuts so full and clear that nothing which can be portrayed in this manner may be wanting to afford the reader a clear understanding of his subject.

Taking the chapter as a whole, the inquirer may derive from it a very intelligent idea of the construction of the locomotive and its working; but to do this, the matter must be closely and exhaustively studied. It must be studied as scholars study their lessons—consecutively and painstakingly—not hurried nor cursorily.

The accompanying cuts portraying the locomotive (some fifty in number), taken in connection with other illustrations embodied herein (of locomotives), leave nothing to be said on the subject. In pursuing the theme, it will help the reader to a more clear conception of



Side View of Locomotive.

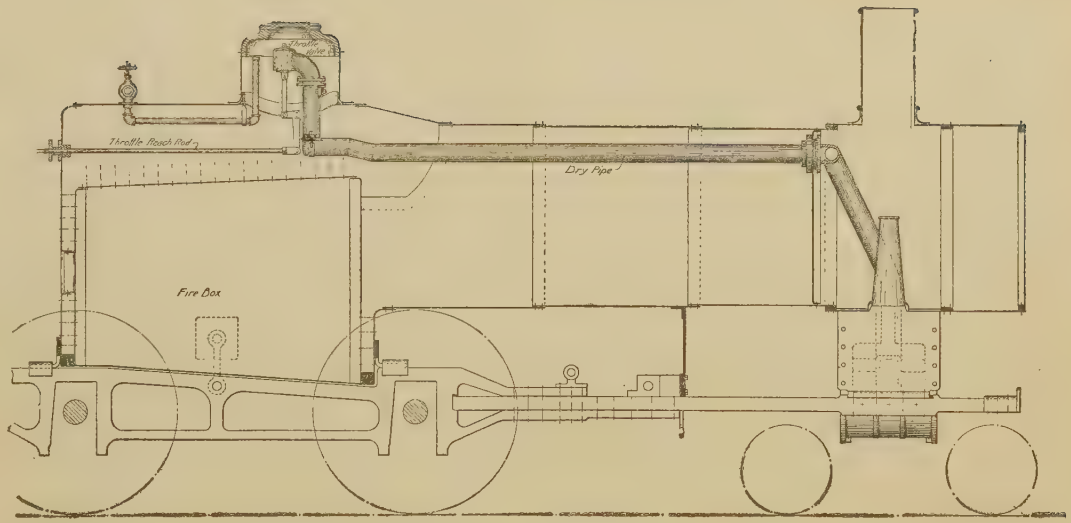
1 Main barrel of boiler. 2 Fire box. 3 Ash pan. 4 Rear section of frame. 5 Front section of frame. 6 Cylinder. 7 Steam chest. 8 Pilot. 9 Driving wheels. 10 Coupling rod. 11 Main rod. 12 Cross head. 13 Valve stem. 14 Link. 15 Eccentric rod. 16 Rocker shaft. 17 Equalizer. 18 Springs. 19 Cab. 20 Steam dome. 21 Sand box. 22 Bell. 23 Smokestack. 24 Head light. 25 Extension end for spark arrester. 26 Truck wheels. 27 Reversing lever. 28 Reversing lever reach-rod. 29 Injector. 30 Injector feed-pipe 31 Check valve. 32 Hand rail. 33 Cylinder cock reach-rod. 34 Boiler hanger to frame. 35 Foot board. 36 Sand pipe. 37 Overflow pipe. 38 Spring hanger. 39 Hand hole. 40 Cinder gondola. 41 Axles. 42 Crank pin. 43 Headlight step. 44 Number plate. 45 Automatic coupler. 46 Saddle casting. 47 Whistle. 48 Cylinder cocks. 49 Forward brace. 50 Fulcrum to equalizer. 77 Truck frame. 81 Lubricator pipe.

NOTE—In further illustration of the Standard American locomotive the reader is referred to the graphic picture, Plate I, entitled "The American Steam Locomotive." It particularizes the different parts of the locomotive and gives the technical names by which they are known among those connected with the locomotive department of railroads. It is at once a chart and an encyclopedia, each part of the locomotive being given a number, so that it may be recognized and quickly referred to.

the locomotive if, before taking up this chapter seriatim, he will go through it and examine beforehand the cuts illustrating the locomotive in detail. Afterward he may take up the chapter as a whole in the order in which it is presented here.

Mankind looks upon the locomotive as complete—as a perfect entity. This, however, is a mistake. Many problems in connection with it are still unsolved, or, at least, only partially so. The difficulty has been, and is, to accomplish within a compass so limited, within confines so narrow, in connection with so restless and unstable a body, what the ingenuity of man seeks in vain to attain satisfactorily where every condition is favorable.

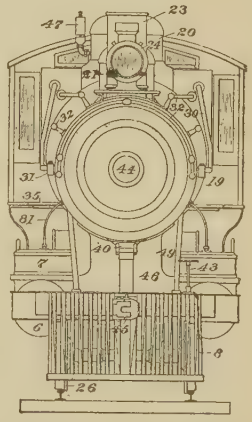
I shall not attempt to point out specifically the defects of the locomotive, but merely to describe it as it is. In doing this, however, I shall indirectly call attention to the things yet to be achieved; at least it will have this effect with experts and others familiar with the machine and its limitations. And in relation to the parts which are apparently perfect, they are but steps



Longitudinal Section of Boiler.

Showing throttle, dry-pipe and means of fastening boiler to frame. The steam from the dome above the boiler is let into the dry-pipe by the opening of the throttle. It passes thence into the live-steam channels, through which it is carried to the cylinders.

on the ladder leading to something better. It will, for this reason, do good to keep them prominently in mind. Man grows, and, with him, the appliances he uses. All that is necessary to ensure his utensils being bettered is that he should set to work to make them better. The second object I have in view in describing the locomotive is to familiarize those who have no practical knowledge of it (and never will have) with its construction and working. Every railroad man should possess this knowledge. Without it his education is incomplete. Its possession will broaden his intelligence and render him more valuable to the company he serves. This truth is so self-evident that it does not need argument or illustration.



Front View of Locomotive. For names of the parts shown above see side view of the locomotive preceding this.

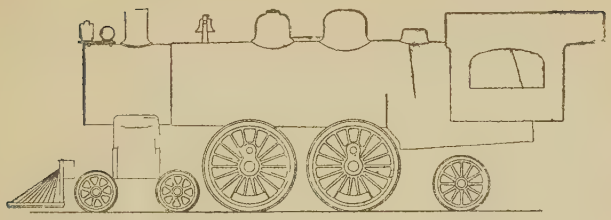
The end sought in a locomotive is to draw the load desired with the least expenditure, including in the latter material and wear and tear. In the case of passenger engines speed is a factor. In Great Britain it is also a factor in connection with freight or goods trains. Many railroads are neither straight nor well constructed and ballasted. In such cases wear and tear are intensified.

The locomotive has been aptly described as having, like the human body, legs, backbone, lungs and stomach. The comparison, however, stops short of brains, yet so much brain power has been hammered into the machine during its construction that it answers to its governing power with all the swiftness and accuracy of the human system. The accompanying illustrations graphically portray the analogy.

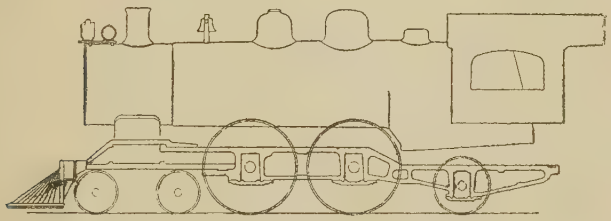
The legs (Fig. 1) are the wheels which carry the whole weight. Upon these wheels is superimposed the backbone (Fig. 2), an iron or steel frame running the whole length of the locomotive, on which is placed almost the entire weight, which it in turn distributes on the wheels, the drivers taking the greatest share to get the necessary adhesion. The frame consists of two sections like the accompanying illustration, some four feet apart and bolted together at various places.

In the cylinders (Fig. 3) the actual power is developed, and, with their appurtenances, they may be called the lungs.

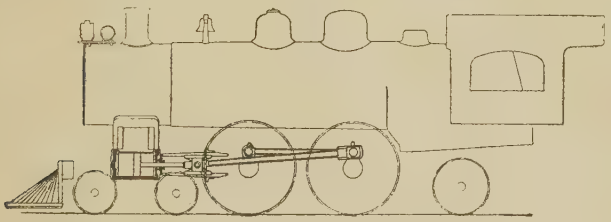
The stomach (Fig. 4) is the largest part, and gives the general appearance to the whole. It is nothing but an immense boiler with a firebox under it.



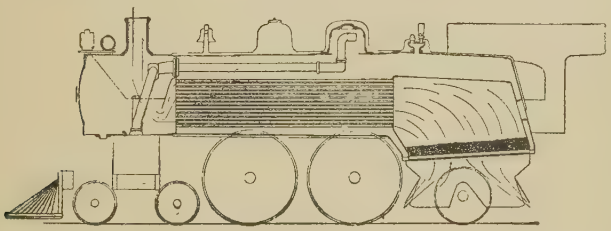
THE LEGS *FIG. 1*



THE BACKBONE *FIG. 2.*

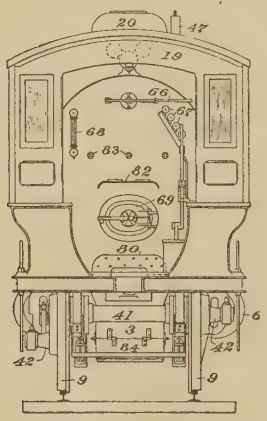


THE LUNGS *FIG. 3.*



THE STOMACH *FIG 4*

In constructing the machine the builder calculates the cylinder power of the locomotive needed to move the load required, over and above the amount necessary to overcome weight of locomotive, friction, air resistance and the inertia of the machine. The ability of the locomotive driving wheel to carry forward a load (without slipping) is said to be equal to about one-fourth of the weight on the rail under each driver.* In order to secure tractive power, therefore, required weight proportionate to the load to be hauled must be placed on the driver. It must also be remembered that tractive resistance is dependent upon speed. In practice the weight placed on the axles of the driver, and so on the wheel and rail, must be proportionate to the strength of the rail; this limitation, therefore, influences and deter-

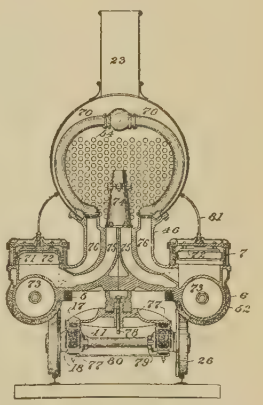


Rear View of Locomotive. The parts shown above, not included in the side view of the locomotive preceding this, are as follows: 66 Throttle lever. 67 Gauge or water cocks. 68 Water gauge. 69 Fire door, 80 Frame tie. 82 Oil-can shelf. 83 Plugs at arch support pipes. 84 Damper.

* The general practice of builders in America is based on the theory that for passenger engines the weight on the drivers is equal to four to one pound of tractive power; freight engines four and one-fourth to one, and for switch engines four and one-half to one; or, in other words, in the last case, four and one-half pounds of weight to every pound of tractive power. The Master Mechanics' Association of America endorses this formula.

mines the power of the machine. Speed is further a factor in this, that it increases the destructive force on the rails.

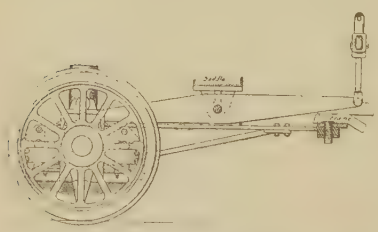
Locomotives may be divided into four classes, each especially adapted to the service it is designed to perform; namely, those used for switching cars at stations or yards, freight traffic, ordinary passenger traffic, suburban traffic. Switching engines usually have four or six driving wheels, upon which, in most instances, the whole weight of the locomotive rests. The drivers are made to bear the entire weight in order to afford the adhesion necessary for starting heavy trains quickly and at frequent intervals. These engines also have short wheel bases to enable them to go around sharp curves and over switches branching from the main track at sharp angles. The wheels are placed near together, usually between the smoke box and fire box. The short wheel base of the switching engine renders it unfit for general traffic, because of the unsteady



Sectional Views of Locomotive, through the exhaust chamber (at the left) and the live steam chamber (at the right). The parts shown above not included in the side view of the locomotive preceding this, are as follows: 52 Lagging. 70 Pipes carrying dry steam to live steam channel (76). 71 Slide valve. 72 Valve cover. 73 Piston. 74 Exhaust nozzle. 75 Channel carrying exhaust steam from cylinder to smoke-stack. 76 Live steam channel, carrying steam to cylinder from dry steam pipe. 78 Truck center pin. 79 Truck axle collar.

motion produced when running at a high rate of speed.

In the case of passenger trains the light load to be hauled permits placing a part of the weight of the locomotive on supporting wheels or trucks. The trucks carry the front part of the engine. One pair of driving wheels is usually placed behind the fire box and another pair in front. In many instances the drivers are increased to six, and, in some cases, to eight. This does not increase the adhesive power of the locomotive, but it does decrease the weight on each pair of wheels, thereby distributing the total weight on the rails over a longer wheel base, and thus making the locomotive less hard on the roadway. If the same weight were put upon one pair of driving wheels that is placed upon four or more, the locomotive would have the same tractive power and, with the same cylinder power, could pull a greater load than when more drivers are used, because the extra friction of the wheels would be avoided. While one or two pairs of drivers are generally sufficient for a passenger engine, three or four, perhaps five pairs will be used in the case of a heavy goods or freight locomotive. The driving wheels of

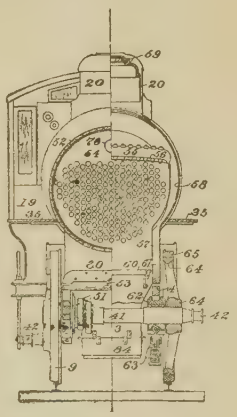


Side View of American Bogie (or Pony) Truck, supporting forward end of locomotive

the latter are usually smaller than those of the former.

It is required of trains employed in suburban service that they should be able to stop and start quickly. To do this, the locomotive must have more than the usual proportion of adhesive weight to prevent its slipping, and the main valves must be so constructed as to quickly admit steam to the cylinders and exhaust it therefrom.

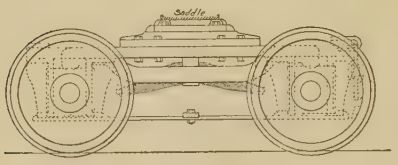
Speed is dependent upon the velocity of the pistons. This is achieved through multiplicity of reciprocations, that is, the reciprocations multiply the rapidity with which the steam acts upon the pistons; but, as this is limited, it becomes necessary to increase the size of the drivers in order to secure the maximum speed desired. This is why passenger engines have large wheels, while engines not required to make great speed have smaller ones.



Sectional Views of Locomotive, through the forward driver (at the left) and the fire box (at the right). The parts shown above not included in the side view of the locomotive, preceding this, are as follows: 51 Eccentrics. 53 Reversing gear spring case. 54 Flues. 55 Crown-bar. 56 Crown-sheet. 57 Inside shell of fire box. 58 Outside shell of fire box. 59 Dome castings. 60 Grate. 61 Mud ring. 62 Journal box. 63 Spring hanger to journal box. 64 Driving wheel castings. 65 Driving wheel tire.

The velocity required in hauling a load is dependent upon the pressure of steam on the pistons. For this reason the

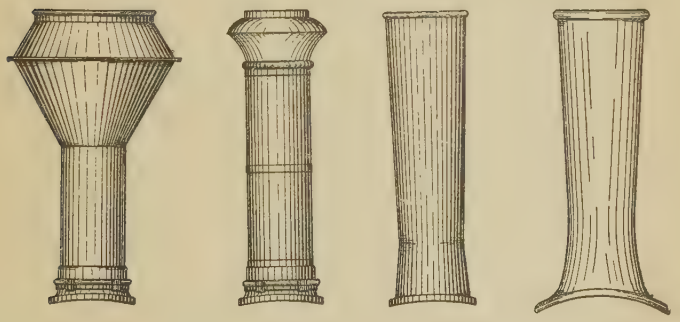
power, it is apparent, must be proportionate. This, however, depends upon the steam producing quality of the boiler.* The steam generating capacity of a boiler depends, *a*, upon the size of the grate and fire box, *b*, upon the amount of heating surface provided, and, *c*, the draught produced by the blast or exhaust steam. In the case of stationary engines the great area of the fire box and the facility (or draught) afforded by a high chimney cheapen and amplify the production of steam. In the case of a locomotive the fire box is restricted, while the height of the smokestack is inadequate. How then is it possible to produce sufficient heat (consume sufficient fuel effectively) to generate the quantity of steam required; to maintain the water in the boiler at the desired temperature; to maintain, in fact, a steam pressure of, say, one hundred and sixty pounds to the square inch? It is through enforced consumption of fuel—by forcing the fire, so to speak. This is accomplished, in the main, by the draught occasioned by the escaping steam through the exhaust pipe into the smokestack. It is further assisted by dampers at each end of the ash pan



Side View of American Locomotive Truck, supporting forward end of locomotive.

* The formulas or rules governing these relations are found in the working tables used by constructors of locomotives.

(which latter is placed immediately below the fire box) to afford the requisite amount of air, and secure through the intervention of such dampers a due consumption of the gases and carbon. The escaping steam through the smokestack serves to create a partial vacuum which, the heat from the fire box hastening to fill, creates in turn a strong draught and in so doing hastens the ignition and consumption of the



Evolution of the Coal Burner Smokestack.

fuel. Some engines are provided with an appliance or lever which controls, from the cab, the intensity of the blast caused by the exhaust steam. In other ways, also, free steam from the boiler may, when necessary, be discharged through an auxiliary blast pipe into the chimney; but, while a strong draught is secured by exhausting steam into the smokestack, a serious difficulty is experienced, in the use of soft coal especially, in supplying the requisite air to

the fire box. This could be drawn wholly from beneath were it not for the impossibility of thus securing due consumption of the carbon generated by the heat as it escapes through the unburned fuel on top of the fire. To obviate this a second damper is placed higher up in the fire box, usually in the fire door. The consumption of fuel is further heightened by careful, I may say scientific, firing. As a rule, we may assume, when we see great volumes of black smoke issuing from the smokestack of a locomotive, that care is not being exercised in firing or that the engine is being overworked. To obviate the smoke annoyance (for it is an annoyance to mankind under all conditions) many forms of smoke burners have been introduced, both for locomotives and stationary engines. The need for them, however, and the added cost they entail, would not be necessary if proper care were exercised in firing.

In working, the fire is regulated from the cab of the locomotive by levers attached to the ash-pan dampers. Thus the quantity of air passing through the fuel is controlled. The door through which the fuel is conveyed to the fire box is also made use of to regulate the quantity of air.

The supply of steam required from a locomotive boiler is more irregular than from any other kind of a boiler. Thus, when a train is ascending a heavy grade the fire must be urged to its greatest intensity. When the top is reached

the demand measurably ceases and steam is generated less rapidly. The irregularity, however, is not so great in a large boiler as in a small one. The former may also be more economically used.

In order to create the required draught, when rapid combustion is required, in a small boiler, the exhaust nozzles must be contracted. By this means the back pressure on the pistons is increased and, if the blast becomes very violent, more or less unconsumed coal is carried through the flues and escapes through the smoke stack. In addition to this waste, more or less of the gases in the fire box escape, there not being sufficient time for their combustion. Moreover, a boiler so small that it must be worked to its maximum at all times cannot afford a reserve of water at a high temperature which may be brought into use when necessity requires. On the other hand, a boiler of greater capacity can store heat for such use when not working to its maximum capacity.

The heating surface of a locomotive is made up of the sides of the fire box, the flue sheet, crown sheet, and tubes or flues placed within the boiler. The quantity of water converted into steam by one pound of coal depends upon the quality of the coal used and the construction of the locomotive boiler. The average performance of an ordinary locomotive varies from five to seven pounds of water to one pound of coal. Locomotive boilers consume in the neighborhood

of twenty-five hundred pounds of coal per hour, according to the work performed. The maximum amount of combustion per hour is, approximately, one hundred and twenty-five pounds of coal to each square foot of grate surface. This requires twenty square feet of grate surface to burn twenty-five hundred pounds per hour. For each square foot of grate surface from fifty to seventy-five square feet of heating surface are necessary. Quality of fuel, however, has much to do in governing the proportion of the heating surface to the grate surface. Wood and good bituminous coal do not require so large a grate as anthracite coal or poor fuel.

The limited surface of water possible to be heated directly by the fire box is overcome by the flues in the boiler of the locomotive. The draught occasioned by the steam blast through the smoke-stack draws the flames and generated heat into the flues and, as these flues are enveloped in water, the latter quickly becomes heated. This is, as is well known, the simple explanation of the generation of steam in the locomotive boiler. As it increases in force it finds its way (when the throttle is opened) into the cylinders and thus affords the power that, through the pistons, propels the machine on its way. The heating surface of the tubes, or flues, varies, of course, on different engines according to the size of the boiler and the power required. A large locomotive may have tubes with a heating surface of eighteen hundred square feet which, with

the heating surface of the fire box amounting to, say, two hundred feet, will afford a total heating surface of two thousand square feet. The approximate evaporation of such a boiler may be estimated at thirty-five hundred gallons of water per hour, or, say, four hundred and ninety cubic feet.

A small tube of a given length affords a greater amount of heating surface in proportion to the space it occupies than a large one, and as the size and weight of the locomotive boiler are necessarily limited and the required amount of heating surface must be obtained within that space, small tubes are employed. However, because of their liability to become stopped up with particles of unconsumed fuel or cinders, a tube of less than two inches diameter is not thought to give the best results. Moreover, small tubes may be made of thinner metal than large ones, and by their use the heat from inside is thus more rapidly conducted to the water in the boiler than when heavier metal is used. This, when rapid combustion is taking place, is, as may be supposed, an important advantage.

The number of tubes in a boiler is regulated with a view to affording the water sufficient space in which to circulate freely and the steam to escape. In this last connection it must be borne in mind that the rising steam produces a certain disturbance (ebullition) of the water, which, if adequate space is not provided, will result in particles of water being raised and carried with the

steam into the cylinders, producing what is technically called "priming." Aside from the loss of power and inconvenience this engenders, the pistons, cylinders and cylinder heads are thereby endangered through the undue strain thus brought to bear.

The boilers of locomotives were formerly made of wrought iron, but soft steel has, to a great extent, taken its place. The latter is of more uniform quality than iron, and is thought to be better adapted to resisting the great strain upon it. Material used for boiler plate must be tough, ductile and tenacious, and of close and uniform texture, in order to satisfactorily meet the requirements of the situation. The plates of the boiler are fastened together with rivets which are inserted when red-hot into holes in the plates. When the rivets cool they contract and, in doing so, draw the plates more closely together. The seams are then tightened by calking. As the seams are manifestly the weakest portion of the boiler plate, it is necessary that care should be exercised to make them as strong as possible.

The boiler and other steam chambers of the locomotive are overlaid with wood or some plastic material which hardens and which is also, so far as possible, a non-conductor of heat, so as to prevent its loss by radiation. This covering is more or less commonly known as boiler lagging. It is covered with Russia iron or sheet steel in order to hold it in place and to present a better appearance as well.

The cylindrical part of the boiler containing the water (through which the flues from the fire-box pass) is required to be of sufficient strength to withstand the lateral and end strain. The formation of the boiler being a complete cylinder renders the former comparatively easy. The other is more difficult. The strain at the forward end of the boiler is overcome, in a measure, by the aid of the tubes and partly by longitudinal stay-rods. In connection with the fire box so many flat surfaces are presented that it is necessary to increase the bracing to make up for the lack of strength due thereto. This is done by means of stay-bolts passing through from the outer to the inside sheet and riveted over on both ends. The crown-sheet, of the old crown-bar type, is secured by crown-bars running across the entire width of the fire box, and the crown-sheet is supported by bolts running from the bottom of the crown-sheet to the top of the crown-bar and secured by bolts or rivets; the crown-bars are also re-inforced by braces which are secured to the dome and wagon-top of the boiler. The radial stay type of fire box is circular in form and is secured by stay-bolts. The type of fire-box boiler known as the "Belpaire" is similar to the crown-bar fire box, with the exterior sheets flattened, the sides conforming to the shape of the crown-sheet of the fire box and secured by stay-bolts.

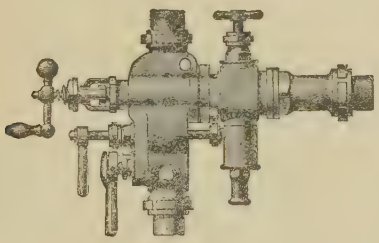
The practices by which the safety of the boiler is made secure are not uniform, because of the

shape of the fire box, and for other reasons. These practices are not, therefore, susceptible of complete elucidation here. Moreover, the obscure nature of the obstacles to be overcome prevents the matter being clearly understood, except by the use of models or practical examination of the machine itself.

In practical working the boiler of a locomotive must contain sufficient water to cover every part of the metal exposed to the heat in and from the fire box, otherwise it will be quickly weakened and ruined through over-heating. It is practicable to keep the boiler filled with water to a height of six or eight inches above the top of the crown-sheet (i. e., the roof of the fire box). A steam space is provided in some designs above the water line by elevating the outer shell of the boiler over the fire box. A cylindrical dome projects from the top of the boiler, and it is from this reservoir that the steam is precipitated through the dry steam pipe into the cylinder. The reason the steam is first collected in this reservoir instead of being drawn directly from the space above the water, before described, is because dry steam is more effective than wet steam and, as dry steam rises above wet steam, the dome permits their separation.

Water is supplied to the boiler, to take the place of that which has been converted into steam, by an injector. This is a device or force pump for supplying the boiler with water without the intervention of the machinery of

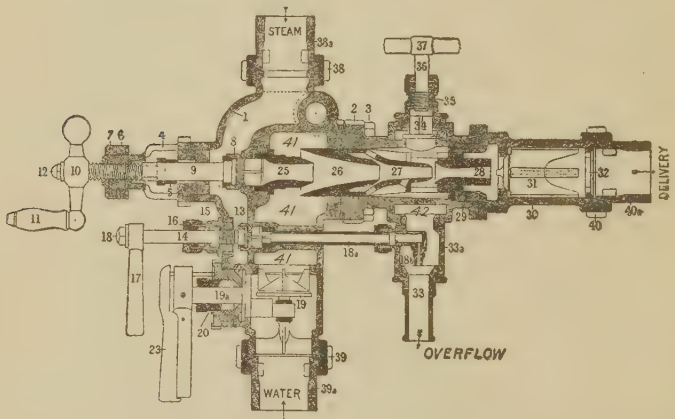
the locomotive farther than the introduction of a jet of steam from the boiler into the injector. The jet of steam is brought into contact with a supply of water from the tender and the water is by this means forced along with the condensed steam into the boiler. While simple in operation, the injector never ceases to excite the admiration of those who observe its working. It is to the unscientific mind very much like a man raising himself from the ground by his boot straps. Its working is, however, in accordance



Side View of an Injector.

with well known laws. The injector is usually placed inside the cab, where it will be under the immediate eye of the engineer. I have described the injector in connection with the supplying of the boiler with water before referring to any other method for accomplishing this end, because it is superior to all others. It is in very general use. However, as a precautionary measure, some locomotives are still supplied with the diminutive apparatus known as a donkey engine, operated by steam

from the engine, by which the engineer may at will (in the event the injector should not work) force the water from the tank into the boiler.

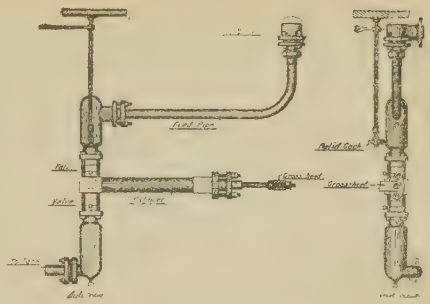


Section of an Injector. Operation: Valve 19 is opened by means of lever 23, which admits water into chamber 41. Valve 13 is then opened by means of lever 17, which admits steam into tube 18a, escaping into overflow, thus creating a partial vacuum in chamber 41 by means of communication, through chamber 42, with valve 34 open, drawing water from tank into chamber 41, nozzle 26, and escaping at overflow. When water thus appears, valve 8 is opened by means of lever 10, admitting steam into nozzles 25, 26, 27 and 28, forcing check valve 31 open and forcing the water already in chamber 41 into delivery pipe, thus supplying the boiler. Water is regulated by valve 19. To shut the injector off, valve 8 is closed.

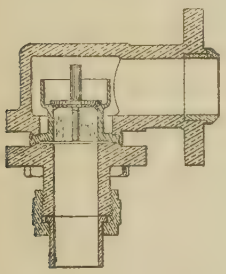
1 Body (back part). 2 Body (front part). 3 Body screw. 4 Yoke. 5 Yoke gland. 6 Yoke packing nut. 7 Yoke lock nut. 8 Steam valve disc and nut. 9 Steam valve spindle. 10 Steam valve handle. 11 Steam valve rubber handle. 12 Steam valve top nut. 13 Jet valve disc and nut. 14 Jet valve spindle. 15 Jet valve bonnet and nut. 16 Jet valve gland. 17 Jet valve lever handle. 18 Jet valve top nut. 18a Jet tube. 18b Lifting nozzle. 19 Water valve. 19a Eccentric spindle. 20 Water valve bonnet. 23 Water valve lever handle. 25 Steam nozzle. 26 Intermediate nozzle. 27 Condensing nozzle. 28 Delivery nozzle. 30 Line check. 31 Line check valve. 32 Stop ring. 33 Overflow nozzle. 33a Overflow chamber with nut. 34 Heater cock check. 35 Heater cock bonnet and nut. 36 Heater cock spindle. 37 Heater cock T handle. 38 Coupling nut—steam end. 39 Coupling nut—water end. 40 Coupling nut—delivery end. 41 Water chamber. 42 Vacuum chamber. 38a Tail piece—steam end. 39a Tail piece—water end. 40a Tail piece—delivery end.

NOTE.—The principle of the injector is fully described and illustrated in another volume.

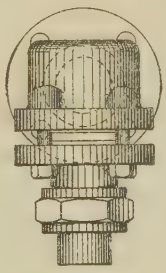
The boiler may also be supplied with water by a force pump operated by a plunger connected to the cross head of the locomotive, as shown by the illustration. Still other devices are known for supplying the boiler with water, but as they are now rarely, if ever, used, an explanation of them here is unnecessary. A check valve is usually placed at the end of the pipe where the water enters the boiler. Its object is to prevent a back flow of water from the boiler, the valve being closed automatically by the water pressure in the boiler.



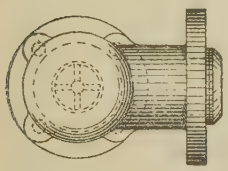
Force Pump.—Water is drawn from the tank into the cylinder through a valve which closes immediately when the motion of the plunger is reversed; at the same time another valve is opened through which the water is forced into the boiler.



Section



Elevation.



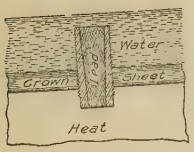
Plan.

Check Valve, for preventing water from returning.

The boiler is fed and the supply regulated according to the amount of work being done by

the engine. If the water in the boiler is too high, the steam space is thereby diminished and more or less water is carried into the cylinders with the steam. The strain thus produced by the movement of the piston is liable to break the cylinder. If the water is too low, on the other hand, the crown-plate, or sheet, is in danger of becoming over-heated and explosion is liable to result. The height of the water in the boiler is ascertained by the use of gauge cocks and a glass water gauge. The former, usually three or more in number, are placed at the rear end of the boiler three or four inches apart. The lower one should be placed two and one-half inches above the crown-sheet. The upper one should be slightly above the highest point at which water is to be carried, which, it is proper to say, is determined by the diameter of the boiler. If the water is at the proper height, steam will be discharged from the upper cock when open and water from the lower one. Should the upper cock discharge water for any length of time, it indicates there is too much water in the boiler. On the other hand, if steam is discharged from the lower cock, it is at once apparent that there is not enough water in the boiler. The water gauge is a steam tight glass tube from twelve to fifteen inches in length, communicating by means of brass elbows with the steam in the boiler at the top and the water in the boiler at the bottom. Each elbow contains a valve worked by a handle and screw. When

both valves are opened, steam rushes into the tube at the top and water at the bottom, and the height of the water in the tube will be on a level with the surface of the water in the boiler. What are very generally known as safety plugs are used for guarding against the danger arising from not having enough water in the boiler. These plugs are hollow and made of brass or cast iron, and filled with some metal that will melt at a low degree of heat. They are placed in the highest part of the crown sheet. In case the crown sheet should become over-heated, the metal in the plugs melts and runs out, thus creating openings by which the pressure in the boiler is relieved and warning given by the escaping steam.



Section of Boiler Fuse Plug.

An important appliance of the locomotive is the safety-valve, designed to prevent the steam pressure in the boiler from exceeding a certain limit. There is a tradition in America that a captain on a Mississippi river steamer, who was racing with the boat of a rival line, sat on the safety-valve of his engine in order that no particle of the steam should escape. This is cited as the acme of daring and foolhardiness. Two valves with which the device is provided are placed in the top of the dome, so that in case one should get out of order the other may operate. They are so constructed that whenever the pressure of

steam exceeds the limit which the boiler is supposed to be able to safely bear, the valve opens automatically and the steam is afforded a means of escape. The noise of the steam rushing through the safety-valve is lessened by dividing or breaking up the current before it emerges into the air. With the modern device for using steam in connection with the injector, already described, surplus steam which would otherwise escape through the safety-valve and be wasted is, in a measure, utilized by the engineer. There are various forms or patterns for the safety-valve. No device has received greater attention than this; yet, with all the thought given to the matter, it is still not satisfactory. A form very common in America is represented in the accompanying illustration.

Section of Safety-Valve.

The steam gauge is another important device. It is an instrument by which the number of pounds of steam pressure per square inch is indicated by an index or pointer on a dial.*

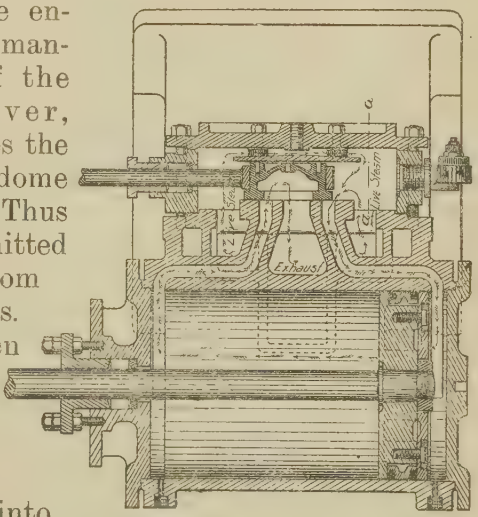
Exterior of Steam Gauge.

We often speak of a locomotive as an engine. This is proper in one sense, and improper in another. The locomotive is propelled by two engines fed from a common boiler. The steam cylinders operating these engines vary in size. A

*The automatic lubricator has become an essential part of locomotives, and is fully illustrated and described in another volume.

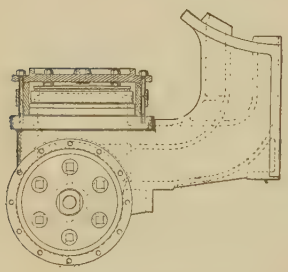
Exterior of Steam Gauge.

form very common in America has a bore of eighteen inches diameter, and a stroke of the piston of twenty-four inches. By the stroke of the piston is meant the distance it moves in the cylinder. This distance is twice the length of the crank, measured from the centers of the shaft and crank-pin. Absolute accuracy is required to be observed in boring the cylinder. Briefly summarized, the operation of the engine is as follows: The engineer, by the manipulation of the throttle lever, opens or closes the valve in the dome of the boiler. Thus steam is admitted or shut off from the cylinders. On pulling open the throttle the steam finds its way from the steam-chest into the cylinder through a passage (or port) devised for that purpose. The arrange-



Section showing action of steam in single expansion cylinder. Piston shown in section.

ment of the valve and its movements are such that the ports through which steam is admitted into the cylinder are, alternately, each open during only a portion of the stroke of the piston. The steam enters the cylinder at one end, and in doing so forces the piston (which moves back and forth in the cylinder) to its opposite extremity. After the piston has made a part of its distance (stroke) the port through which steam is passing into the cylinder closes without allowing the steam thus admitted to escape until the piston has nearly reached the end of its journey. In operation, the expansive action of the steam admitted to the cylinder exerts a diminishing pressure on the piston until the exhaust port is opened. When the stroke is completed the steam escapes through the exhaust port into the air. At the instant the steam ceases to act (i. e., at the completion of the stroke) a new supply is admitted at the other end of the cylinder, thus forcing the piston back to the opposite extremity, when the exhaust steam escapes, as before. It is this constant action and re-action of the piston within the cylinder that transmits power to the piston rod and thence to the coupling rod, which in turn is attached to the



End View of Cylinder (cylinder head removed) with the steam chest shown in section at "a" "a" of preceding illustration.

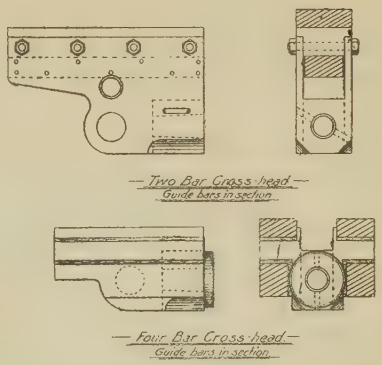
crank pin or (if it is an inside-cylinder engine) to the crank shaft, thus causing the driving wheels to revolve.

The action of the steam within the cylinder is very simple. It is, however, the key to the whole situation. In regard to the mechanism of the cylinders, accurate adjustment of the valves for admitting the steam and allowing it to escape, and the due proportion of the parts, are absolutely essential to the smooth and economical working of the machine. The piston must be steam tight. It is prevented from leaking at the sides by metal packing. The pressure of the piston against the sides of the cylinder is equal to the pressure of the steam within the cylinder. The orifice through which the piston rod works in the end of the cylinder is also made steam tight by the use of packing. Speaking on this subject, an authority on such matters says: "The piston is made steam tight against the side of the cylinder by elastic metallic packing. Many kinds of metallic pistons are in use, but I know of none so good, for locomotive purposes, as that simple one invented by Mr. Ramsbottom, which bears his name, and which consists merely of a few grooves (three commonly) turned in the piston body, into which are sprung pieces of D-shaped wire (for the rings are little more) which press outward against the interior of the cylinder, and bear upon it with steam-tight contact. It is, of course, desirable that while the piston should move steam-tight in

the cylinder, it should also move with the least possible friction. . . . In order that a piston may be safe against leakage, it is necessary that the ring should bear upon the cylinder with a pressure at least equal to that of the maximum force of steam within the cylinder, because if this condition be departed from, and if steam leak in at any part between the surface of the ring and the interior of the cylinder, it will press upon the ring, drive it backward, and will pass on; but this pressure is a pressure per inch of surface, therefore the less surface there is in contact, the less will be the actual pressure, and the less, therefore, will be the actual friction; obviously, for these reasons, it is desirable to diminish the width of the bearing surface of the rings as much as possible in practice, and that it is which is done in the Ramsbottom piston. Moreover, the use of such a piston diminishes the wear upon the cylinder, while the wear of the rings is unimportant, as although they may require frequent renewal, say every six months, their total cost, even in a large locomotive, is only a few shillings."*

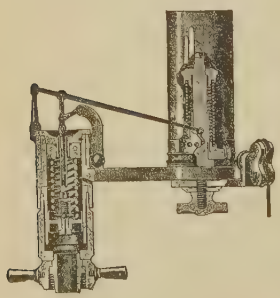
Continuing our description, the end of the piston rod farthest from the cylinder is attached to a square piece of metal or cross head which works back and forth in a rigid horizontal frame running parallel with the piston rod. In many cases the frame is on the side of the piston rod, but sometimes above it. This frame is called a

* Mr. John Wolfe Barry.



guide bar. Its purpose is to prevent the connecting rod, in the rotary motion given it by the crank pin, from deflecting the piston rod from the exact angle at which it enters and traverses the cylinder. In some instances the connecting rods of the locomotive are attached to the crank shaft between the driving wheels. In such cases the cylinders are also placed within the frame of the locomotive, i. e., between the wheels. These are called inside cylinders. When the connecting rods are attached outside of the driving wheels to the crank pin, the cylinders are called outside cylinders. Both forms have adherents, but the judgment of constructors and operators inclines more and more to the outside cylinder. The inside form has the merit of a shorter steam passage and greater facility in securing the cylinder and keeping it heated; also in more secure fastenings for the guide frame, and avoidance of interference with the bars which couple the drivers together. Other advantages might be named, but the crowded space within which the cylinders with their appurtenances must be placed, and the increased cost of constructing axles with the crank forgings, together with other

objections, more than offset the advantages of the inside cylinder. In the case of outside cylinders the natural difficulties which attend the coupling of the drivers are increased by the necessity of attaching the connecting rod to the outside face of the wheel. On the other hand, the slight resistance (friction) attending its working compared with the considerable resistance of the connecting rod when fastened to the axle between the drivers more than offsets any objections. By placing the cylinder outside, necessary space is left beneath the boiler for the gearings. Outside cylinders must, per contra, be set on brackets where they can not be kept hot. Moreover, the steam must travel a long passage, relatively, to reach them. These are serious objections. However, notwithstanding these objections and still others which might be named, the practice of putting the cylinders outside the wheels and frames is very general in America. In some parts of Europe, and especially in England, the inside cylinder is more favorably regarded.



Section of Indicator.

The steam pressure in the cylinder may be known at the various points of the stroke of the piston by the use of an indicator designed especially for that purpose.

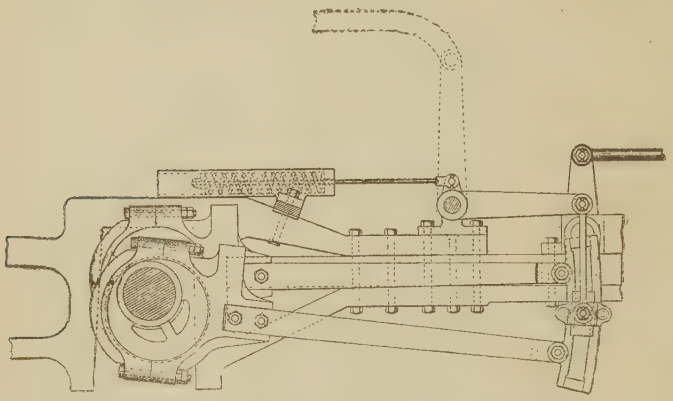
In its practical working the steam acts upon a piston, upon which rests a spiral spring, which is

graduated to suit the pressure under which the engine is working. The piston is coupled to the pencil arm by means of a parallel motion, and the pressure in the cylinder is recorded upon a card which has been placed around the drum of the indicator referred to above.

As the fixtures of the locomotive have grown in number and the size of the cylinders has increased, rearrangements of the cylinders and valves have from time to time been found necessary. This has, perhaps, been more true of inside than outside cylinder engines, there being in the latter case abundant space. As regards the construction of the cylinder, there is practically no difference between the inside and the outside forms. Reference has already been made to the packing used in connection with the cylinder, including that designed to prevent the escape of steam through the opening through which the piston rod works. The head of the cylinder (i. e., the forward end), is fastened on with bolts so it may be easily removed whenever necessary to remove the piston, or for any other reason.

A locomotive is enabled to run either backward or forward by having two contrary eccentrics for each cylinder; one is fastened to the shaft in such a position as to move the valve so the engine will run forward; the other is set so that the engine will move backward. These eccentrics are attached to the opposite ends of a link by means of eccentric straps and rods. The

purpose of this link is to change the direction of motion of the engine by bringing the eccentric blade of the desired motion in contact with the rocker arm and for giving the required cut-off.



Side View of Eccentrics, Straps and Reversing Gear.

When a link is placed with the block at one of its ends, steam will follow the piston nearly to the end of the stroke and as the link is raised or lowered, so as to bring the link block toward the center of the link, the cut-off is shortened. The rocker arms are connected by rods, called valve stems, to the main valves.*

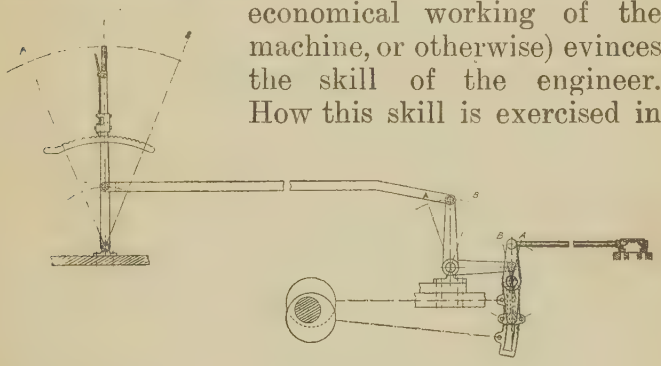
End View of Reversing Gear.

The links are suspended to the ends of arms by bars, called link hangers. These arms are attached to what is called a lifting shaft, which also has another upright arm attached to it on the right hand side

*Full description and illustrations are given in another volume.

of the engine. This arm is connected by a reversing rod to a reversing lever, worked by the engineer in the cab of the locomotive. Its movement raises or lowers the link.

The method of governing the action of the slide valves and the admission of steam to the cylinders (and consequent smooth operation and economical working of the machine, or otherwise) evinces the skill of the engineer. How this skill is exercised in

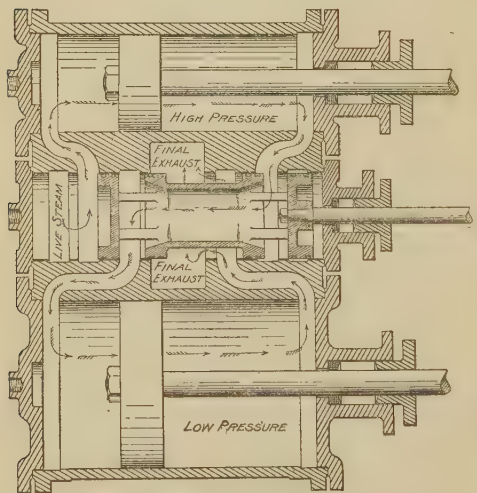


Engineer's Lever in Connection with Reversing Gear.

controlling the expansion of the steam in the cylinder rather than the opening and closing of the valve which admits steam into the cylinder, can not be explained with sufficient perspicuity to be of sensible aid to the student. The subject is pre-eminently one of practical knowledge, and what little can be gained from books by the new beginner is given in another volume.

I do not esteem it necessary here to further describe the apparatus by which the action of the piston in the cylinder is brought to bear on the driving wheel, and so on the train.

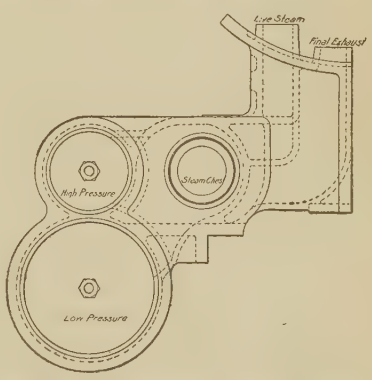
All the connecting rods and shafts must, it is apparent, be relative in length, size and strength to the other parts of the machine; harmony must exist throughout. This is true also of the boiler and cylinders, which must be proportionate to the load to be hauled and the speed to be attained. These details, incomprehensible to the novice, are achieved by following well-known practices of construction, aided by demonstrated formulas for ascertaining the tensile strength of the various metallic parts of which the machine is made. These parts, so generally made of iron at one time, are now almost universally made of steel.



Section showing action of steam in compound cylinder.

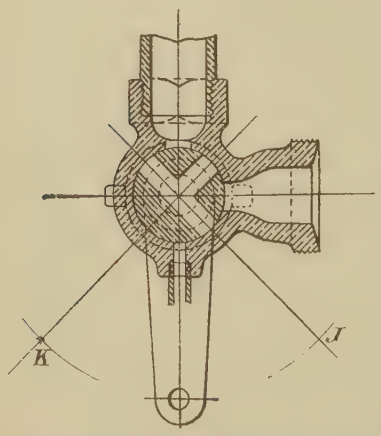
There are two forms of locomotives. One is known as the simple or single expansion locomotive; the other as the compound locomotive. Among the thingsclaimed for the last named is that it saves fuel because of the greater degree of expansion of the steam.

Its advocates claim that after the steam has acted upon the piston of one cylinder (the high-pressure) it is conveyed into a larger cylinder (the low-pressure), where it expands and acts again upon another piston before being finally exhausted through the smokestack. The four-cylinder compound locomotive has a high-pressure and low-pressure cylinder on each side of the engine. The two cylinders (high and low pressure) of the type illustrated, are cast in one piece, with a valve chamber and saddle. The valve which allows the steam access to the cylinders is of the piston type. It is double and hollow and works in a cylindrical steam chest in the saddle of the cylinder casting, between the cylinders and the smoke box. This valve controls the steam admission and exhaust of both the high and low-pressure cylinders. The steam which is exhausted from the high-pressure cylinder becomes at once the supply for the low-pressure cylinder. When the front bars of the locomotive frames are double, the low-pressure cylinder is placed on top, and the double rail prevents the use of the ordinary



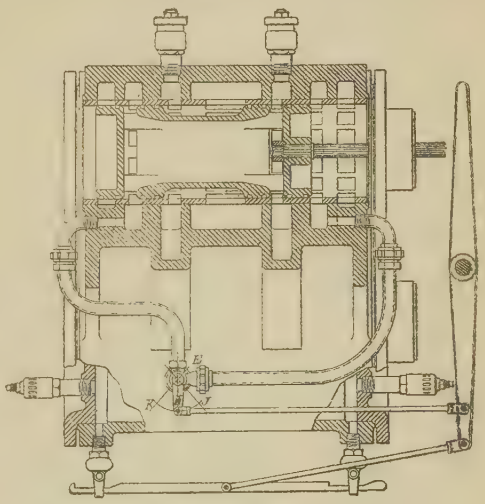
Front View of Compound Cylinder (cylinder heads removed).

rocker shaft and box. The valve motion is then what is called direct acting, changing the location of the eccentrics on the axle in relation to the crank pin. When the front rails are single bars, the low-pressure cylinder is under the other and the eccentrics are placed in the usual position. In such case the valve motion is called indirect acting. The most common method of transferring the motion from the links to the valve rod is by means of a rocker arm, the link block being connected with the lower end of the rocker arm, and the valve rod to the upper arm. Before starting the locomotive, steam is admitted to both the low and high-pressure cylinders. For this purpose a starting valve is provided, which is opened to admit steam to pass from one end of the high-pressure cylinder to the other, and thence through the exhaust to the low-pressure cylinder. It is operated by the same lever which operates the ordinary cylinder cocks. To secure harmony, however, and to prevent the locomotive becoming logy, this valve is kept closed as



Section of Starting Valve and Relief Cock. Compound Cylinder. Position "J" for starting; position "K" for high-pressure cylinder relief cock.

much as possible. Besides the usual air valves placed in the main passage of the high-pressure cylinder and also in the admission ports of the low-pressure cylinder, additional air-valves are placed in the low-pressure cylinders to prevent the formation of a vacuum which would draw cinders into the steam-chest and cylinders. To prevent rupture in case of excessive pressure, water relief valves are attached to the front and back cylinder heads of the low-pressure cylinder. The compound engine is generally similar to the ordinary single-expansion locomotive, except in the respects pointed out.*

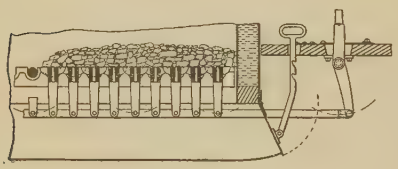


Application of Starting Valve and Relief Cock, Compound Cylinder.

The grate of a locomotive usually consists of cast iron bars so arranged that they may be easily moved or shaken. Grates designed for

* The subject of compound-cylinder engines *versus* single-expansion cylinder engines is also referred to in the chapter on "The Evolution of the Locomotive" in this volume, but more particularly and in great detail, and with profuse illustrations, in another volume.

burning anthracite coal are sometimes constructed of wrought iron tubes, through which a current of water circulates in order to prevent the grate from becoming over-heated. Cinders and burning coals are prevented from falling through the grate upon the railway track by an ash pan, made to fit as closely as possible inside.

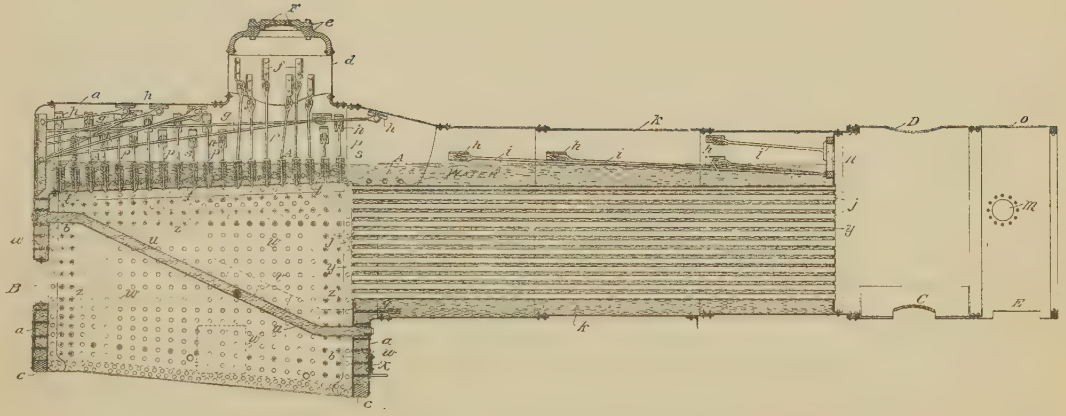


Section Showing Grate and Damper.

Dampers are provided for increasing or shutting off the draught, as required. The fire box, which affords room for the burning fuel, is usually a rectangular box, about three feet wide, made of iron or steel plates. These plates are so arranged as to form an inside and an outside shell, having a space between them, called a water space. This space varies on different locomotives from two and a half to four and a half inches. The inner shell in many cases is made of copper plates, and has a flat top called the crown-sheet, or crown-plate. In America soft steel has taken the place of copper. The top of the outside shell is generally arched. The two shells are united by what is more or less generally known as a mud-ring, which closes the water space between the two shells at the bottom. As the water in the cylindrical part of the boiler of the locomotive has free contact with that in the water space of the fire box, the shells of the

latter are exposed to the steam pressure, the strain upon the outer and inner shells being in opposite directions. In order to resist the pressure thus brought to bear upon them, they are strengthened and held together by stay bolts screwed through the outer and inner plates at short distances from each other. The ends of these stay bolts are securely hammered down after being inserted into the plates. As much depends upon the strength of these bolts, subjected as they are to the expansion and contraction of the steam in the boiler, they are made of the best quality of material. In the case of a crown-bar fire box, the crown-sheet is strengthened by strong iron bars bolted thereto and connected to the outside shell by braces or sling stays. The tubes or flues of the boiler are attached to the front plate of the inner shell of the fire box. This plate is called the flue sheet, and is rigidly stayed to the cylindrical part of the boiler by braces at the bottom of the latter. These tubes carry the smoke and products of combustion from the fire box to the smoke box and so on out at the chimney or smokestack.

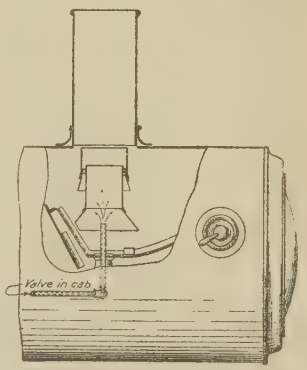
There are two main methods of firing a locomotive; one is known as the banking system, the other the spreading system. The former, it is thought, may be used to advantage when the coal is comparatively free from clinkers. The coal is banked or piled in the back part of the fire box and sloped downward toward the front of the grate where it is kept at a white heat.



Longitudinal Section of Locomotive Boiler Filled With Water.

a Boiler shell. *b* Inside shell of fire box. *c* Mud ring. *d* Dome shell. *e* Dome castings. *f* Dome lugs. *g* Rear longitudinal stays. *h* Shell lugs. *i* Forward longitudinal stays. *j* Flues. *k* Barrel plates. *m* Manhole opening. *n* Dry pipe ring. *o* Extension end. *p* Sling stays. *q* Inside shell brace. *r* Dome sling stays. *s* Crown-bars. *t* Crown-sheet. *u* Arch support water pipe. *v* Brick arch. *w* Stay bolts (solid). *x* Frame tie. *y* Flue sheets. *z* Stay bolts (hollow). *A* Cross stays. *B* Fire door. *C* Saddle opening. *D* Smokestack opening. *E* Gondola opening. *F* Safety-valve connections.

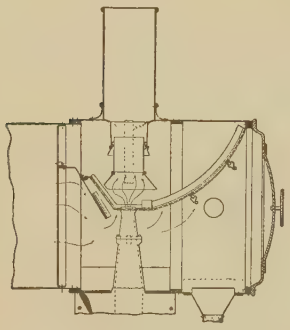
The coal in the back part of the fire box gradually cokes and thus the gases are expelled. The consumption of these gases is aided by the admission of air at the furnace door, which mixes with them. When the bank of coal at the back of the fire box becomes coked, it is pushed forward onto the glowing fire and more coal put in its place to go through the same process. The spreading method of firing, referred to above, is used when the coal contains clinkers. The coal is evenly spread in a thin layer over the entire grate. The success and economy of this method depend upon the regularity with which the fire is fed and the layer of coal maintained; also upon the proper admission of air above the fire. The layer of coal is thicker when the engine is working hard than when it is doing light work. To obtain the best results, intelligence and observation must be exercised by those in charge here as elsewhere.



Part Section of Boiler, Showing Blower.

In order to create a draught when the locomotive is standing still, either before leaving the round house or at any other place, there is a device for letting steam into the smokestack directly from the boiler. This steam represents an expense, as it takes so much live steam from the boiler, while that

from the cylinders, having already performed its office, does not. Because of this, or from a desire to husband the supply of steam in the boiler, or because of forgetfulness, the device in question for creating a draught is not always used.



Section Showing Spark Arrestor, used with Extension Front Ends.

Another device of the locomotive is the spark arrester, placed below the smoke-stack above the flue openings. In some countries the use of this device is required by law. Besides abating a nuisance, it is useful as a precaution against setting fire to property along the track.

PARTS OF THE LOCOMOTIVE.

The parts which manufacturers of locomotives buy in the market from other manufacturers are indicated by an asterisk (*).

Air Pump Exhaust Pipe.
Arch Brace.
*Air Cocks.
*Air Signal Hose.
*Air Brake Hose.
Arch Hand Rail.
*Air Pump Lubricator.
*Air Gauge.
Ash Pan Damper Handle.
Air Drum Bracket.
*Air Drum.
Ash Pan.
*Air Brake Pump.
*Air Cut Out Valve.
*Air Pump Governor.
*Air Strainer.
*Air Pump Throttle.
Buffer Beam.
Blower.
Balance Plate.
Balanced Valve.
Bridges.
Back Cylinder Head.
*Boiler Lagging.
*Boiler Jacket.
*Boiler Sheets.
Bell.
Bell Stand.
Back Up Eccentric.
Back Up Eccentric Rod.
Back Up Eccentric Strap.
*Blower Cock,
*Brake Valve Reservoir.
*Branch Pipe.
Cinder Chute.
Cinder Chute Slide.
Cleaning Door.
Cylinder.
Cylinder Saddle.
Cylinder Head Casing.
Cylinder Lagging.
Cylinder Cocks.
Cylinder Cocks Rigging.
Cylinder Casing.
Cross Head Pin.
*Cross Head. (If steel, they purchase.)
Counter Balance Spring and Rig.
*Check Valve.
*Check Valve Case.
Circumferential Seam.
Crown Bars.
*Chime Whistles.
Cab.
Cylinder Cock Lever.
*Cylinder Lubricator.
Cab Bracket.
Counter Balance Weight.
Dry Pipe Joint.
*Draw Bar.
*Draw Head.
Deflector Plate.
Deflector Plate Adjuster.
Draft or Petticoat Pipe.
*Driving Wheel Tire.
*Driving Wheel Centers. (They purchase if steel; if cast iron, they make.)
*Driver Brakes.
Driver Springs.
Driver Spring Hangers.
Driver Spring Equalizers.
Driver Spring Hanger Brace.
Driving Box Shoe.
Driving Box Wedge.
Driving Box.
Driving Axle.

*Delivery to Drum.
*Drip Cock.
*Dry Pipe.
Dry Pipe Hangers.
Dome.
Dome Cap.
Dome Casing.
Extension Front.
Exhaust Port.
Engine Truck
*Engine Truck Wheel. (If cast iron they make; if wrought iron or steel they purchase.)
*Engine Truck Tire.
Engine Truck Axle.
Engine Truck Brass.
Engine Truck Box.
Engine Truck Pedestal.
Engine Truck Frame.
Engine Truck Pedestal Brace.
Engine Truck Frame Brace.
Engine Truck Equalizer.
Engine Truck Spring Hanger.
Engine Truck Spring.
Engine Truck Spring Band.
Engine Truck Spring Pocket.
Eccentric Connection. Back Up.
Eccentric Connection. Go Ahead.
Expansion Pad.
Expansion Link.
*Engineer's Brake Valve.
Flagstaff.
Front Frame.
Front Cylinder Head.
*Flues.
Frame Brace.
Frame Splice.
Fire Door.
Feed Pipe Hanger.
*Feed Pipe.
*Feed Pipe Hose.
*Fire Box Sheets.
Guides.
Guide Yoke.
Guide Block.
Go Ahead Eccentric.
Go Ahead Eccentric Rod.
Go Ahead Eccentric Strap.
Grate Shaking Rig.
Gauge Lamp.
Gauge Cocks.
Hose Hangers.
Headlight Step.
Headlight Bracket.
*Headlight Case.
*Headlight Reflector.
*Headlight Burner.
Horizontal Boiler Seam.
Hand Rail.
Hand Rail Brackets.
Hand Hold.
*Injector.
*Injector Overflow.
*Injector Throttle.
Jacket Bands.
Key.
Link.
Link Block.
Link Block Pin.
Link Hanger.
Lower Rail of Frame.
Main Rod.
Main Rod Front Strap.
Main Rod Connection.
Main Frame.
Number Plate.
Netting.
Nozzle Stand.
Nozzle Tip.
Nigger or T Head.
Oil Pipe Plug.
Oil Pipe.
Oil Can Shelf
Pilot.
Petticoat or Draft Pipe.
Piston Packing.
Piston Rod.
Piston Head.
*Piston Packing Rings.
*Pump Connection.
Pedestal Brace.
*Pump Piston Packing.
*Pump Exhaust Connection.
*Pump Steam Connection.
*Pump Valve Case.
*Primer.

Parallel or Side Rod.
Pilot Bracket.
Quadrant.
Relief Valve.
Rocker.
Rocker Box.
Reach Rod.
Rod Bush.
Rocking Grates.
Running Board.
Reverse Lever.
*Signal Lamp.
Smoke Arch Door.
Smoke Arch Front.
Smoke Arch Ring.
Stack Base.
Smoke Stack.
Steam Chest.
Steam Chest Casing Cover.
Steam Chest Cover.
Steam Passages to Chest.
Steam Ports.
Safety Hanger.
*Signal Pipe.
Suspension Stud.
*Steam Bell Ringer.
Sand Box.
Sand Box Lever.
Sand Pipe.
Side or Parallel Rod.
*Steam Cylinder Brake Pump.
*Steam Pipe.
*Steam Valve.
Sling Stays.
*Stay Bolts.
Stand Pipe.
*Safety Valves.
*Steam Gauge.
Steam Turret.
*Signal Whistle.
Sand Lever.
Shake Lever Stub.
*Signal Pipe.
*Signal Pipe Hose.
T or Nigger Head.
Truck Center Casting.
*Truck Brake.
*Train Pipe Connection.
*Train Pipe.
Tumbling Shaft.
Tumbling Shaft Arm.
Tumbling Shaft Lever.
*Tube Sheet.
Throttle Pipe.
Throttle Valve.
Throttle Bell Crank.
Throttle Stem.
Throttle Lever.
*Train Pipe.
*Train Pipe Hose.
Tail Piece of Frame.
Valve Yoke.
Valve Stem.
*Valve Stem Packing.
Valve Seat.
Valve Stem Rod.
Ventilator.
Wheel Guard.
Wash Out Plug.
Wedge Bolt.
*Water Pipe.
*Water Valve.
Whistle Rig.
*Whistle Signal Valve.

TABLE SHOWING
EVOLUTION OF THE LOCOMOTIVE.

Year.	Designer of Engine.	Builder of Engine.	Name of Engine.	Class of Engine.	DIMENSIONS OF													
					CYLINDERS.			HEATING SURFACE.			WHEELS.				WEIGHT.		Steam Pressure in Lbs. to Sq. Inch.	Length of Boiler. Ft. In.
					Inside or Outside.	Diameter in Inches.	Stroke in Inches.	Fire Box Area in Sq. Feet.	Tubes Area in Sq. Feet.	Total Fire Box Tubes in Sq. Ft.	Number Driving Wheels.	Diameter Driving Wheels in Inches.	Number Truck or Bearing Wheels.	Diameter Truck or Bearing Wheels in Inches.	Weight on Driving Wheels in Lbs.	Weight of Engine in Running Order in Lbs.		
1803	Trevithick			Freight	Inside	8	54				4	54	..	...	...		...	6 0
1812	M. Murray	M. Murray	Blenkinsop	"	"	8	20				..	..	4	42	...	...	...	
1814	G. Stephenson	G. Stephenson	Blucher	"	"	8	24				4	36	..	..	...	...	...	8- 6
1825	G. Stephenson	Stephenson & Co.	Locomotion	"	"	10	24				4	48	..	...	...	13000	25	10 4
1826	Stephenson & Co.	Stephenson & Co.	Experiment	"	Outside	9	24				6	48	..	...	...	...	...	10- 4
1828	Stephenson & Co.	Stephenson & Co.	Lancashire Witch	"	"	9	24		66		4	48	..	...	...	...	...	9- 0
1829	G. & R. Stephenson	G. & R. Stephenson	Rocket	"	"	8	$16\frac{1}{2}$	20	$117\frac{7.5}{100}$	$137\frac{7.5}{100}$	2	$56\frac{1}{2}$	2	...	...	8500	50	6- 0
1830	Stephenson & Co.	Stephenson & Co.	Invicta	"	"	10	18				4	48	..	...	...	...	40	10- 0
1830	Stephenson & Co.	Stephenson & Co.	Northumbrian	Pass'ger	"	11	16			$411\frac{7.5}{100}$	2	60	2	...	8025	14675	...	
1830	G. Stephenson	R. Stephenson & Co.	Planet	"	Inside	11	16	$37\frac{8.5}{100}$	$370\frac{4.1}{100}$	$407\frac{8.6}{100}$	2	60	2	36	10250	16000	...	6- 6
1830	Stephenson & Co.	Stephenson & Co.	Mercury	"	"	11	16	$37\frac{8.6}{100}$	$370\frac{4.1}{100}$	$407\frac{8.8}{100}$	2	60	2	36	10250	16000	...	6- 6
1832	G. Stephenson	R. Stephenson & Co.	Comet	Freight	"	12	16	$37\frac{9.0}{100}$	$302\frac{9.9}{100}$	$340\frac{2.0}{100}$	4	60	..	...	...	18950	...	7-12
1832	T. Hackworth	R. & W. Hawthorn	Wilberforce	"	Outside	$14\frac{3}{4}$	16				6	48	..	...	...	...	...	
1833	Carmichael & Co.	Carmichael & Co.	Earl of Airlie	"	"	11	18				2	54	4	...	...	19000	...	
1834	Stephenson & Co.	Stephenson & Co.	Patentee	Pass'ger	Inside	12	18				2	60	4	...	...	...	...	
1834	Stephenson & Co.	Stephenson & Co.	Atlas	Freight	"	16	20				2	54	4	54	...	34000	...	
1834	G. Forrester	Vaughan F'dy	Swiftsure	"	Outside	11	18				2	60	4	...	...	...	...	
1835	Hawthorn & Co.	Hawthorn & Co.	Comet No. I	Pass'ger	Inside	12	16	35	237	272	4	48	..	...	...	...	60	
1837	R. Stephenson & Co	R. Stephenson & Co	North Star	"	"	16	18				2	84	4	48	...	...	...	
1838	Haigh Found'y Co	Haigh Found'y Co	Grand Jct. Ry	"	"	$13\frac{3}{4}$	18	58	480	538	2	72	4	48	...	...	...	
1838	T. E. Harrison	Hawthorn & Co.	Hurricane	"	"	16	20	108	516	624	2	120	..	...	...	...	...	
1839	Haigh Found'y Co	Haigh Found'y Co	Hector	"	"	16	20			688	2	54	4	54	...	...	120	
1846	D. Gooch	Great Western Co	Great Western	Express	"	18	24			1767	2	96	6	..	...	...	...	
1847	F. Trevithick	London & N.W. Co	Cornwall	"	"	$17\frac{1}{2}$	24				2	102	6	..	...	...	...	
1848	T. R. Crampton	Bury, Curtis & Kennedy	Liverpool	"	Outside	18	24	154	2136	2290	2	96	6	48	24000	70000	...	12- 6
1859	J. Ramsbottom	London & N.W. Co	Problem	"	"	16	24				2	$91\frac{1}{2}$	4	...	...	54000	...	
1861	J. E. McConnell	London & N.W. Co	Delaware	"	Inside	18	24	$242\frac{5.0}{100}$	$980\frac{3.0}{100}$	$1222\frac{8.0}{100}$	2	$91\frac{1}{2}$	4	...	28000	69400	150	
1870	M. Kirtley	Neilson & Co	Midland Ry. 800	"	"	17	24	103	993	1096	4	80	2	...	...	71850	140	
1871	M. Kirtley	Midland R'y	Midland Ry. 890	"	"	17	24	92	1020	1112	4	80	2	...	...	73400	140	
1885	S. W. Johnson	Midland R'y	Midland Ry. 1738	"	"	18	26			1261	4	84	4	...	30000	85475	160	$10\text{-}10\frac{1}{8}$
1886	Nielson & Co	Nielson & Co	Caledonian 123	"	"	18	26				2	84	6	...	34000	83800	150	
1889	T. W. Worsdell	North Eastern Co	N. E. Co. 1518	"	"	20&28	24			1139	2	$91\frac{1}{2}$	6	...	35500	93350	175	
1891	Wm. Dean	Great Western Ry	G. W. Ry. 3010	"	"	20	24	$123\frac{8.8}{100}$	$1321\frac{8.4}{100}$	$1444\frac{9.2}{100}$	2	92	4	...	38000	88200	160	
1892	P. W. Webb	London & N.W. Co	L. & N. W. Co	Freight	"	$19\frac{1}{2}$	24	$114\frac{7.9}{100}$	$1130\frac{4.0}{100}$	$1245\frac{1.9}{100}$	8	$53\frac{1}{2}$	..	...	...	93675	160	15- 6

CHAPTER II.

ENGINE FAILURES AND BREAKDOWNS.

There is, perhaps, no subject that occupies the thought of the locomotive engineer (and necessarily, also, the engine fireman) more than that of engine failures due to breakdowns on the road. It is the spectre that eternally haunts him, intruding even on his slumbers through dreams that sometimes picture the most fantastic dilemmas and disasters.

It is in the moment of emergency that the engineer may show his mettle; so long as everything goes as it should and each particular piece of mechanism of his engine responds with precision to the pulsating steam released by the throttle, so long as every foot of the track is perfect and his train glides along smoothly and conforms to the schedule with the exactitude of the chronometer, ordinary intelligence may cope with the task of engine-running. But the emergency, which sooner or later comes to all, occurs. It is then the man is tried. Simple intelligence is not sufficient—that must be supplanted by courage, nerve, resource, even genius. But ability to apply quickly the knowledge is the thing. Lack of this quality, or of the knowledge, may paralyze the traffic of a division or a road and hesitation or ignorance may

cause the destruction of life or property.

No book, of course, can directly supply the qualities required by those upon whom great responsibility rests in moments of unexpected danger. But, indirectly, such book knowledge may contribute much towards making men brave, collected and resourceful. The great general achieves his conquests through bravery born of an undaunted confidence in himself, because he has mastered the science of war as set forth in books that reach back to the great Cæsar of Rome. And so the engineer, if he has the knowledge, will, in the hour of emergency, be cool, collected and resourceful, and be the master and not the slave of any untoward circumstance. This knowledge will be particularly valuable when it becomes necessary to modify certain methods, as in disconnecting or blocking when certain parts are disabled, and in fastening and chaining in connection with the springs, driving boxes and other parts, besides enabling the engineer to perceive in advance what should and must be done if some particular part breaks or becomes deranged.

In this book the subject of engine breakdowns is dealt with. It is not pretended that it treats of every particular kind of emergency that may arise. It would be impossible, first, to collate every kind, or, if collated, to include them all in a book—a hundred books would not suffice. Moreover, each of the numerous classes of locomotives has peculiarities of construction (and it may be said that each locomotive has its individual peculiari-

ties), so that each engineer must familiarize himself with the details of the mechanism and construction of the locomotive he operates, so that he may readily apply the principles here laid down. It would manifestly be impossible to prescribe in detail for every class of locomotive in operation. There has, however, been brought together here, scores of typical cases, many of which have arisen in actual locomotive running, and it is believed that familiarity with these will furnish the clue to the meeting of almost any emergency that may occur.

It is not claimed that the answer given in every case indicates the very best solution of the problem stated—"Many Men, Many Minds." Where there is more than one way of doing a thing there will surely be differences of opinion. It can only be said that what are offered here include the conclusions of practical men who have run engines themselves and tell the best they know.* After all, the greatest value of such books as these may be said to lie in the suggestions they offer rather than the actual directions they give. The examples herein set forth are given simply as helps and guides.

Engine failures are generally understood to embrace:

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* Many of the questions and answers relative to locomotive operation were formulated by Mr. W. L. French,. a practical locomotive engineer of great experience; they have been published from time to time in the "Locomotive Firemen and Enginemen's Magazine," and are included herein through the courtesy of Mr. John F. McNamee, its Editor.

1. Delays occasioned by waiting for an engine at an initial terminal (with certain exceptions), and

2. Delays on account of an engine breaking down, running hot, not steaming well, having to reduce tonnage on account of defective engine, causing delay at a terminal or meeting point junction connection.

In connection with the subject of breakdowns it is apparent that supervision of the engine is of the utmost importance. Efficient supervision, both on the road and in the roundhouse, must be constant and thorough. At each arrival and departure careful inspection must be made by both engineer and roundhouse man, and full and explicit reports of such inspections by both will tend to prevent waste of energy and time caused by prolonged debates between departments, through improper charging of failures, and will do much toward the betterment of the service.

It is not only essential that inspection should be thorough, but it is equally important that all failures should be promptly and correctly reported to the proper officials. It is only from this source that the management can know, (1) why traffic is delayed and where the responsibility lies. (2) What defects exist in design or workmanship of motive power and what investigations should be made or action taken to correct them, and (3) whether local conditions, such as the topography of the country traversed, character of the fuel or water, or type of locomotive used, render it de-

sirable to make improvements in the line or increase the efficiency of the motive power.*

In this field of railway operation, as in all others, the necessity and value of co-operation of departments is apparent. Here the engineer can do much by making his reports accurate and definite. It is essential in the proper operation of a railway that the real facts should be known—for instance, whether hot bearings result from the use of freight engines in passenger service, or leakage is caused by excessive delays on sidetracks, and so on. This co-operation between departments is also called for in emergencies, when delays may be minimized by the prompt and intelligent action of the train crew under the supervision of the engineer.

NOTE—A volume of "The Science of Railways Series," is devoted exclusively to the Air-brake, and the reader is referred to it for information relative to air-brake failures. The subject of Compound Locomotives is fully treated in a volume entitled, "Engineers and Firemen's Handbook," to which reference should be made for further information concerning the operation of Compound Locomotives.

* In this connection the reader is referred to the chapters in this volume treating of the Motive Power Department.

CHAPTER III.

THE LOCOMOTIVE AND ADHESION.

Q. 1.—What is a locomotive?

A.—A horizontal boiler, with two high pressure engines and accessories attached to a frame, the whole mounted on wheels and designed to move on two parallel rails.

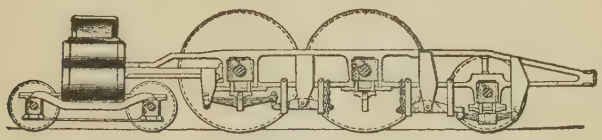
Q. 2.—What is a locomotive commonly termed?

A.—An engine; although a locomotive has two engines that are dependent on each other for the perfect performance of the locomotive but which, in the case of the failure of one engine the other may be used independently but with a great loss of power to the machine. When both engines are in perfect condition one engine is exerting its greatest power at the point where the other one is practically useless as a power exerting medium. This condition is, of course, reciprocal.

Q. 3.—If a locomotive becomes disabled on the road, what should be done?

A.—The train should be immediately protected at front and rear by flags at the prescribed distance, and temporary repairs made as quickly as possible sufficient to enable the train being moved to the first available sidetrack, in order to avoid blocking the line. If only a minor breakdown, requiring but a few minutes to fix, the train should

proceed after the necessary repairs have been made, but under no circumstances should any chances be taken likely to cause a delay to traffic.



Showing What to Do in Case of Broken Main Driving Spring on an Underhung Engine.

In the event a locomotive is taken to a side-track, all repairs possible with the tools available should be made, but if the breakdown cannot be repaired, even sufficiently to clear the main lines, then arrangements should be made to notify the nearest telegraph office, giving location of train and full particulars and asking for assistance. If expedient, a passing train may be flagged and a message to the telegraph office sent thereby.

Q. 4.—Can a train be handled with one side of locomotive disabled?

A.—That depends on the physical characteristics of the road and the nature of the disablements of the engine, as well as the class of locomotive to which the injury occurs. With the lighter class of locomotives and level roadbeds, with the side rods up, 50 per cent or more of a train can be handled, but with an unfavorable grade or with side rods down the engine will do no more than to handle itself. The heavy modern locomotive will do no more than handle itself without side rods up, as with only one pair of drivers to fur-

nish the adhesion to propel the whole weight of the locomotive it will stand and slip and will not handle itself to a terminal.

Q. 5.—How do the engines of a locomotive transmit their power to the driving wheels?

A.—The power exerted by the steam pressure on the piston head is transmitted by medium of the piston rod, crosshead, wrist pin and main rod to the crank pin, which is located on the outside of the driving wheel between the hub and the outer edge of the wheel. This arrangement makes a crank lever of the pin and gives a rotary motion to the wheels, propelling the locomotive and its load in the direction indicated by the position of the reverse lever.

Q. 6.—When is there the greatest danger of damage to the machinery from an engine slipping, when running at a high or low rate of speed?

A.—At a low rate of speed, because at a high rate of speed the revolutions of the wheels are not increased so much over normal as when slipping at a low rate of speed.

Q. 7.—Upon what is the power of a locomotive to do work dependent?

A.—On the energy it can exert to produce motion without the driving wheels slipping, and is dependent on the adhesive power of the locomotive. This power is proportional to the weight on the driving wheels.

Q. 8.—How may adhesion be increased or diminished?

A.—Increased by the use of sand, which makes the friction greater, and lessened by a wet or

frosty rail, which reduces the friction. Sand on a wet rail will give about the same adhesion that a dry rail would have without the use of sand. If the sand lever is opened wide and two heavy streams of sand are run on the rail, friction will be greatly increased on the train wheels and a train "stalled," that could have been pulled with a lighter use of sand, besides exhausting the supply sooner than necessary, which is limited to the none too great capacity of the sand box. The frequent opening and closing of the sand valves will give the best result on a hard pull, for if the valves are left open just a little, to run fine streams of sand, they will speedily close up and the wheels will slip. The quantity of sand that will give the requisite adhesion with the least train friction is what is desired.

Q. 9.—Is there anything aside from a "bad" rail that will cause wheels to slip?

A.—Yes. Too great cylinder power for the adhesion of the wheels. This condition is not intended to exist. A small driving wheel will slip with the same cylinder power more easily than a larger wheel, because greater leverage is exerted.

Q. 10.—What is tractive power in a locomotive?

A.—Its power to pull. It is always less than adhesive power.

Q. 11.—On what is the tractive power dependent?

A.—The length of the stroke, area of piston, average mean effective steam pressure and diameter of driving wheels.

CHAPTER IV.

THE BOILER.

Q. 1.—What part of a locomotive is it the most important to have at all times in a first-class condition, in order to incur the least possible danger of an engine failure when the locomotive is on the road in service?

A.—The boiler.

Q. 2.—Why is it so important a factor in locomotive operating?

A.—On account of it making and containing the steam which performs the work of hauling the train. With a good boiler, free from leaks, under any ordinary condition, plenty of power to do the work will be assured; even when the machinery is much worn, the engine will still be capable of doing good work. All parts of a locomotive should be kept in good condition, but the boiler should be given the greatest care.

Q. 3.—Should a boiler be given good care from the time it is first put in service, or should the care commence when the boiler, from usage, begins to show the need of it?

A.—Good care should be given a boiler from the day it is put in service to get the greatest possible wear out of it and the best results at all times. Because a boiler is new and clean, neglect to wash

it out thoroughly is only laying up future trouble for all concerned, for such neglect means scales and mud in the boiler, and that means leaks. For the fireman to allow the steam to go down and the fire to grow low, because he knows he can "pick her up" whenever he wants to, is breeding more of the same sort of trouble. Proper firing and avoiding the use of the blower, with a low fire most of all, and careful inspection with the repairing of any minor defect that is found, will do much to keep a boiler in good condition.

Q. 4.—What is one of the prime causes of leaky boilers?

A.—Scales and mud banking about the tubes and against the sheets, caused by impure water. They are formed by the evaporation of the water, which causes the carbonate of lime to be precipitated, forming scale. This process continues, and as time goes on the scale becomes thicker and thicker, and the water is thereby removed farther and farther from the sheets, staybolts and flues, with a consequent injury to them. One sign of scale or mud in a boiler is the flue sheet "honeycombing," or coating over when on the road; another is small pieces of unburned coal clinging to the sheets.

Q. 5.—What effect does this scale formation have on the sheets and tubes?

A.—It causes them to overheat, resulting in bulged sheets and collapsed tubes. The sheet becoming too hot grows soft and yields to the pressure from within. It may move slightly away from the scale and allow water to pass in between

and cool the sheet, but eventually the scale will reform, the old process will take place, and as the sheet has lost its elasticity it will remain badly bulged, and unless the scale is removed and hammered back into shape it most likely will give way entirely. Under such conditions the sheet is said to be mud burned.

Q. 6.—What effect has scale on staybolts?

A.—At first it causes only a slight leak. As the scale thickens, the leakage grows worse, and as the sheet distends, the heads of the bolts, as a rule, are torn away. The same is true of crown bolts. When sheets become badly cracked they must be replaced or patched, as new staybolts would not hold in the defective sheets. One broken staybolt adds very materially to the strain on those in its immediate neighborhood, and a broken staybolt should be replaced at the earliest possible moment.

Q. 7.—If a sheet bulges, what should be done?

A.—The fire should be checked at once, and the engine worked under reduced pressure to the terminal, where the sheet should be replaced.

Q. 8.—If a handhole plate or plug is blown out, what should be done?

A.—The fire should be drawn or deadened at once, as this accident would result in the emptying of the boiler. The remedy to be applied depends upon what may have happened. In the case of a handhole plate blowing off, it is usually due to the breakage of a bolt. If the plate could be found, it could be replaced by using another bolt, or a piece of sound wood could be used as a sub-

stitute for the plate. In the case of a plug blowing out, another of soft pine could be driven in its place. After the hole had been closed, the boiler could be refilled, fire built, and steam to a low pressure raised, with which the engine could be run to its destination.

Q. 9.—If a boiler becomes empty on a trip, how can it be refilled?

A.—This is, as a rule, a slow and laborious process. It could be done only by means of pails, and pouring the water in through one of the openings, obtained by unscrewing the whistle, a safety valve, or other part through which free access to the boiler may be had.

Q. 10.—In the event a tube leaks badly or bursts, what should be done?

A.—It is possible to put bursted flues in shape to permit a train proceeding, provided time and conditions allow. The boiler should first be filled quite full of water, in order to offset the loss. Then the steam should be blown off through the whistle, or the release valve should be removed from the chest, and the throttle opened to blow off steam. The fire should be deadened, in order to admit of plugging the flue. Should the flue be burst it ought to be plugged at both ends, but if a flue only leaks at the flue sheet it is unnecessary to do anything beyond plugging the flue. Any starchy material, such as bran, if admitted through the heater cock on the injector after the latter has been started, will aid in stopping a bad leak.

Q. 11.—What effect has frequent caulking on staybolt heads, tubes and sheet seams?

A.—It wears them out rapidly. The bead on the flues wears off, as do the heads of stay and crown bolts, seams of sheets and the edges of cracks. Often one will hear a boilermaker say, "There is nothing left to caulk." It is better, if possible, to avoid the cause of leaking than to apply the remedy.

Q. 12.—What other causes, besides scale or rapid change in temperature or pressure will cause boilers to leak?

A.—Vibration, which occurs most in large engines with long heavy flues. Poor material or poor workmanship, or both, often has much to do with leaky boilers.

Q. 13.—How are staybolt tests made?

A.—By tapping them with a hammer, in the hands of an experienced boilermaker. Staybolts break next to the sheet, and many railroads have small holes drilled lengthwise in the ends of the bolts, far enough to pass inside the sheets, so that when a bolt breaks, steam and water escaping through the hole will be a warning of the breakage. It is not safe to run a boiler with broken bolts, as the load that a bolt carries is immediately shifted to its neighbor when it breaks.

Q. 14.—Where are staybolts liable to break?

A.—In the upper rows at the front end of the firebox. At this point the widest variations of expansion of the two plates united by them takes place. The sidesheets are rigidly fastened together at the mud-ring, and also at the back head.

As the inside sheet is subjected to the direct action of the fire, it is hottest of the two, and therefore expands more. The difference in the expansion of the two plates is subject to constant variation, and this causes a continual bending of the stay-bolts at the inner face of the outside sheet, a bending that will eventually cause fracture.

Q. 15.—If a boiler is liable to leak easily, when on the road, what can be done to avoid it?

A.—A light, hot fire should be kept at all times, thus keeping the sheets from cooling and contracting. Soda ash should be freely used in the tank and the boiler blown out often.

Q. 16.—Will this not cause a fuel waste?

A.—No. While in a sense it is a waste, yet it will prove to be a saving in the end. To allow the boiler to leak would involve a greater expense than the cost of the extra coal thus used; in addition there would be the chance of an engine failure, which should be always avoided if possible.

Q. 17.—What part of the boiler is the most liable to give out and cause an engine failure?

A.—The flues, by one bursting.

Q. 18.—What should be done when a tube bursts on the road?

A.—Plugged with an iron plug furnished for that purpose. The best way is to fashion a wooden plug to fit tightly in the flue; it should be from 12 to 18 inches long and, as tubes often collapse just inside the sheet, it may save a job of plugging the flue in the front end. This plug should be driven in the flue and followed up with an iron one. The wooden plug will swell and

make a safe job of it. The smokebox end should be plugged. This is often a difficult job under favorable conditions, on account of the location of the burst flue, and one that is well-nigh impossible on the road. As a rule, with a burst flue if the engine dies, the best plan is to let her be towed into the terminal and repaired there, as clearing the main line is the vital question now-a-days and it takes too long to do this, even if the means are at hand to fill the boiler after the work has been done.

Q. 18.—If the water level should fall below the line of safety, what should be done to avoid damage to the firebox and boiler?

A.—The fire should be banked with fine coal. If a bad case, water should be thrown on the fire or the fire shaken out altogether. If one knows he is running low on water there is little danger to be apprehended. It is when one thinks there is plenty of water, when as a matter of fact there is but little, that damage is done. Water can not be watched too closely.

Q. 20.—Why does variation of temperature cause a boiler to leak?

A.—It causes the sheets to shrink away from each other, and the tubes to contract away from the sheet. A patch gets hotter than the metal it covers and it is almost impossible to keep one from leaking.

Q. 21.—How can foaming be detected and what should be done when indicated?

A.—Foaming is usually detected by the appearance of water at the top of the stack. First would

shut off steam to allow the water to settle. Then, if there were three gauges of water, the trouble would probably be due to too much water in the boiler. If the water settled down so only one gauge of water was shown, foaming would undoubtedly be the trouble. Foaming is also manifested by a whitish appearance of the steam as it escapes from the stack, cylinder cocks or water gauges, also by the sound it makes which is not a clear whistling noise.

Q. 22.—When boiler is found to be foaming what should be done?

A.—Would open cylinder cocks to prevent the cylinder heads from being knocked off. If equipped with a surface blow-off would open it. Would start left injector to work as well as the right injector in order to raise the water level. Would shut off steam at frequent intervals, and allow the water to settle, so its true level could be ascertained and not allowed to rise too high or fall too low. If necessary, would reduce the speed.

Q. 23.—What should be done when priming?

A.—Would shut off the injector, lower water level and check the fire to lessen the rate of evaporation.

Q. 24.—What should be done to check or stop foaming of oily water?

A.—Would put a piece of sulphate of copper or blue vitriol in the supply pipe. This frequently stops foaming due to oil or grease, provided no alkali had previously been put in the water. Would get the blue vitriol at a local telegraph office.

Upon arriving at a water station would allow the tank to overflow freely, so that the oil which would rise to top of the water could be run off. By putting on the heater at the same time this method of getting rid of the oil is further facilitated.

Q. 25.—If water gets low enough to leave the crown sheet uncovered, what should be done?

A.—The engine stopped and the fire banked with earth to prevent the crownsheet from being burned. Then after the boiler had cooled somewhat and the steam pressure had fallen, would start the injector to raise the water level. As soon as water appeared at the first gauge, the fire could be cleaned and engine proceed.

Q. 26.—If a boiler is fitted with a fusible plug and it is melted because the water falls to a low level, what should be done?

A.—This would put out the fire and disable the engine. Therefore would protect the train and prepare to be towed in. But if another fusible or solid plug were available would insert it when steam pressure was reduced and would then fill the boiler again through the safety valve, after which the fire could be started. But this takes too much time as a rule.

Q. 27.—If a flue is leaking badly, what should be done?

A.—If leak was at the tube sheet where the tube is expanded into place could do nothing on the road. If leak were due to a defective tube, and water was blowing through to the firebox, would

plug it, by cutting the end of a pole into the shape of a plug to fit the tube, cutting it so it could be easily broken at that point, as shown in Fig. 1.

Fig. 1.
Sharpened Pole for Plugging Tube.

Would then put this plug in the end of the tube and drive it home, and next would break it at the partially severed point, thus leaving the plug in position as shown in Fig. 2. That part of the

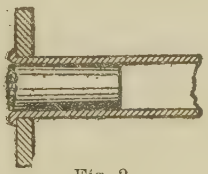


Fig. 2.
Tube Plugged.

plug which projected into the firebox would be burned off, although the plug, being protected by the tube, usually holds in position until terminal is reached. Hence with a plug in, the leaking steam and water would go into the smokebox, whence it would be carried off by the exhaust.

Plugs made especially for doing this work are obtainable but are not ordinarily supplied to locomotives. An illustration of this type of plug is shown in Fig. 3. It is known as the Morgan tube stopper, but can be applied only when engine is

cool. It consists of a cap that sets down over the end of the tube, and is held in position by a bolt which runs through to a similar cap at the other end of the tube.

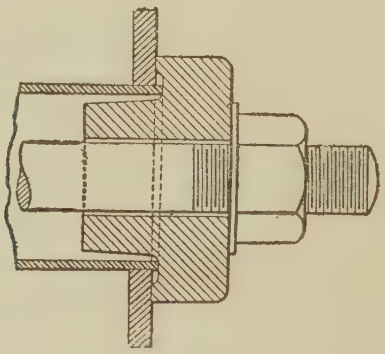


Fig. 3.
"Morgan" Tube Stopper.

Q. 28.—If, when blowing down a boiler, the blow-off cock becomes clogged and cannot be closed, what should be done?

A.—Such a condition would probably result in emptying the boiler enough to expose the crown sheet of the firebox to the action of the fire. Would therefore draw the fire at once. If the bed of coals was thin at the time, it might be possible to draw it away from the firebox sheets and heap it up in the center of the grates and then deaden the whole by shoveling in damp earth, thus choking the fire and keeping the incandescent coal away from the sheets, so as to avoid all possibility of burning.

Q. 29.—How are leaky joints in the exhaust pipe of a locomotive located?

A.—This is not a serious defect, nor one requiring any attention upon the road. Where the air-brake pump exhausts into the passages of the saddle, a leak could be located by plugging or blocking the nozzle and starting the pump with an angle cock open so that no pressure could accumulate in the main reservoir. The pressure of the exhaust, which would be choked by the plug in the nozzle, would cause the steam to escape from any leaks that might exist in the passages or pipes.

In case the air pump did not exhaust into these passages it would be exceedingly difficult to make proper examination. It could be done, however, when the steam was down to from 25 to 30 pounds. The nozzle should be plugged and the wheels well blocked. The throttle could then be opened a little and the reverse lever moved backward and forward. This would put a pressure in the exhaust pipes and passages that would escape from the leaks should there be any.

Q. 30.—When can an engine be best inspected for leaky steam pipes in the front end?

A.—After the fire had been drawn and the boiler allowed to cool, and the temperature of the front end considerably below what it would be with the engine at work, or when just in from a run. Then it would be possible to locate the leaks better than when everything is hot.

Q. 31.—When making repairs while pressure is upon the boiler, is there any danger?

A.—If the metal is grooved or weakened in any way, the jar caused by using a hammer or calking tool might start a crack resulting possibly in explosion. It is safest to make all repairs on a cold boiler.

Q. 32.—If a sheet cracks, what should be done?

A.—Such cracks most commonly appear at the throat sheet, the tube sheet and the side sheets of the firebox. The cracking of a sheet does not necessarily mean that an explosion is imminent. Yet, because a crack is not followed instantly by an explosion it is no assurance that one may not follow immediately. A crack indicates weakness of the boiler, therefore pressure should be reduced at once, by throwing earth on the fire and starting the injector. Then a careful inspection should be made to determine the extent of the injury and the continued movement of the engine or train would depend upon the extent of the damage and the likelihood of its increase.

CHAPTER V.

THROTTLE AND STEAM CONNECTIONS.

Q. 1.—When a throttle valve suddenly becomes disconnected, what should be done?

A.—This accident may occur while the valve is opened or closed. It is usually caused by the connecting pins working out. If it occurs while the valve is closed it renders the engine practically useless. The only way to remedy the difficulty would be to remove the dome cap after the steam pressure had been reduced to zero, and replace the pins. Consequently, when this occurs on the line the fire should be deadened, and the engine disconnected and towed in. If engine is equipped with a drifting valve it can be moved without the train.

If, however, the accident occurs while the throttle is open, the steam should be reduced sufficiently to allow of moving the reverse lever easily and the engine may then be controlled by the reverse lever, but the air brakes should be handled with great care. Should only the hand brakes be available the train crew should be warned to be in readiness to apply them promptly when called for; and at the first opportunity the dispatcher should be informed of the accident.

Q. 2.—In the event of a dry pipe collapsing, what should be done?

A.—Steam should be reduced so as to permit of moving the reverse lever easily and the engine controlled by the lever. Airbrakes should be used with great caution. If necessary to use only hand brakes the crew should be advised of the situation and told to be on the alert to apply the brakes when called for. The accident should be reported as quickly as possible.

Q. 3.—If a throttle valve leaks, what should be done?

A.—This is annoying but not dangerous, and as a rule results from wear, or from the seat or valve cutting from wire drawing. The main thing to provide for is to keep the cylinder cocks open always and the reverse lever in the central notch when at a standstill. In order to determine whether it is the throttle or dry pipe leaking it should be observed whether the steam is dry or wet. Steam leaking through the throttle valve would be dry because the valve is some distance above the water level, but the dry pipe is below the water level, indeed, is sometimes submerged, and therefore more or less water would leak through.

Q. 4.—In the event of either a whistle or safety valve breaking off or blowing out, what should be done?

A.—When the steam has blown off enough to allow of doing so, the hole, which is usually small, may be plugged with hardwood cut to fit and driven well in. Then either could be tied down with the bell-cord or braced in position. Both injectors should be put in operation and run as long

as possible because the water would lower quickly by reason of the steam blowing off through the fracture. It is seldom necessary to kill the fire.

Q. 5.—If a steam pipe bursts or breaks, what should be done?

A.—This is a serious accident and would call for the same general procedure as in the case of a broken steam chest or steam chest cover, with regard to disconnecting main rod and blocking crosshead. In order to stop the flow of steam the broken pipe would have to be removed and a plate bolted over the tee head connection, and to pack it paper felting or wood could be used, as shown in Figure 4. Sometimes it is possible to stop the

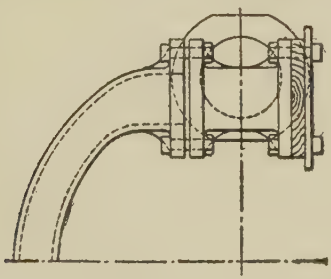


Fig. 4.
Plate Bolted Over Tee Head Connection.

flow of steam for a short time by driving a plug into the tee and bracing it to prevent its being blown out, but owing to the heat of the firebox the wood is liable to shrink and become loose, so this method cannot be depended upon except as a temporary makeshift. When the flow of steam has been stopped and the opening closed, the valve on

the disabled side should be disconnected and clamped, as shown in Figure 5, and the main rod

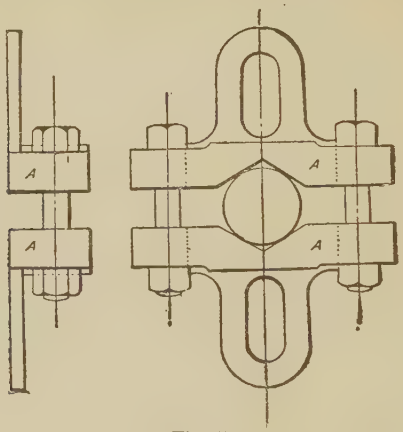


Fig. 5.
Valve Stem Clamp.

should be taken down and the crosshead blocked, as shown in Figure 6.

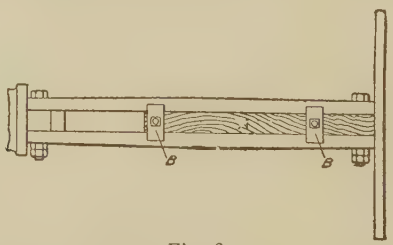


Fig. 6.
Crosshead Blocked with Four-Bar Guides.

Q. 6.—In case the steam pipes leak, what should be done?

A.—Notwithstanding that this results in lessening the steaming efficiency of the engine, no at-

tempt to remedy it should be made while on a run. Reporting it for immediate repair at the end of a run is about all that can be done.

Q. 7.—In what manner may leaking steam pipes be discovered?

A.—When the firedoor is open the steam blowing can usually be heard. But to determine it beyond doubt the front should be opened, then the throttle may be started just a little, which would allow of the leaking steam being seen.

Q. 8.—If a wash-out plug blows out or a blow-off cock would not close, what should be done?

A.—Both injectors should be put at work in an endeavor to overcome the leak long enough to get train into the clear. If, however, that fails, then to prevent the firebox sheets from burning the fire should be drawn. Should the weather be cold or freezing the pet cocks on all the connections, wherever water is likely to collect, should be opened to drain the pipes; if there are no cocks the couplings should be slacked off, the tender hose couplings disconnected, and particular care given to the air pump drain cocks to prevent a rupture of the steam cylinder of the pump. If the throttle becomes disconnected and open the pressure should be reduced until the engine will not slip and the train controlled by means of the air-brake. What is often thought to be a disconnected throttle is nothing but a throttle stuck due to excessive lost motion of the parts which usually occurs when giving full throttle. In such cases the throttle rod should be tapped, as that will often release it.

CHAPTER VI.

DRAFT APPLIANCES.

Q. 1.—How should a displaced petticoat pipe be readjusted?

A.—The purpose of a petticoat pipe is to obtain an even draft over the whole of the tubes. If too high, the most of the draft would pass through the lower rows of the tubes and pull upon the front end of the fire. If too low the draft would be strongest through the upper rows of tubes and the pulling would be at the rear end of the firebox. Therefore the displacement of the petticoat pipe may be readily detected by the action of the fire. Where there is the least draft the tubes will also be choked with ashes and cinders. Therefore, if there be an excessive draft through the lower rows of tubes, the petticoat pipe should be lowered; if through the upper rows, it should be raised.

Q. 2.—Should a diaphragm or deflector plate on the smokebox become misplaced, how may it be readjusted?

A.—The purpose of the diaphragm in the front end of an engine is the same as that of the petticoat pipe. Uniformity of draft is obtained by the adjustment of the lower edge of the diaphragm, which is a separate sheet from the main body. Originally this lower sheet was movable and could

be raised and lowered by a system of levers under the control of the engineer. Now it is bolted to the main plate in such a way as to permit of a limited amount of motion.

Diaphragm displacement is indicated by the uneven action of the draft upon the fire, and a possible collection of cinders in tubes having an insufficient current of gases to keep them clear. If the diaphragm be too high, it would cause an excessive draft through the top rows of tubes, if too low, the same with the lower rows.

For an excessive draft through the upper rows and at the rear end of the firebox, the diaphragm should be lowered. If through the lower rows and at front of firebox the plate should be raised.

General directions for the adjustment of this plate, or for the petticoat pipe that would make it possible to set either to the desired position without trial, cannot be given. It depends upon the type of engine, the service it may be called upon to perform, and also the quality of coal to be burned. The form of diaphragm and front end recommended by the American Railway Master Mechanics' Association is shown in Figure 7.

Q. 3.—If the netting should become clogged or broken, what should be done?

A.—Should the netting become clogged it is apt to seriously interfere with steaming, besides the danger of causing the fire to blow back into the cab.

Clogging is usually caused by an excessive quantity of oil in the cylinders. Where an automatic oiler is used, it does not occur so frequently

as where the cylinders are lubricated from cups in the cab. With this form of lubricator, the opening of the throttle immediately after the oil has

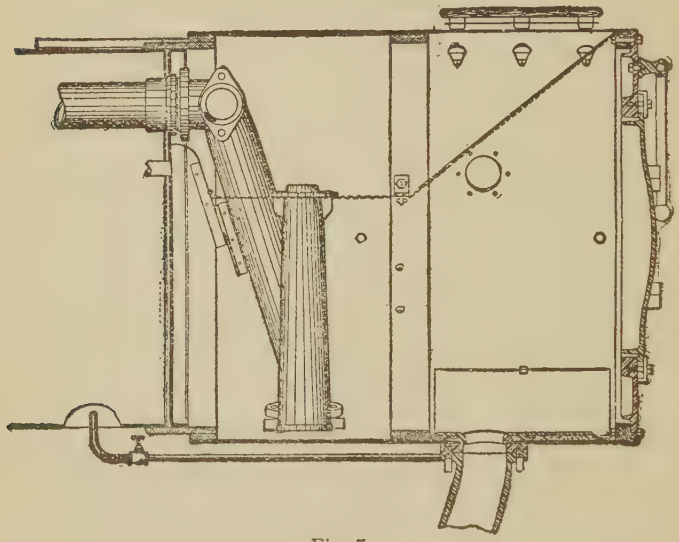


Fig. 7.
Diaphragm and Front End. Master Mechanic's.

been introduced is apt to throw it out at the exhaust nozzle and spatter the netting.

There is danger of throwing out large sparks and starting fires if the netting has been cut or worn away so that there are holes in it. When this happens on the road, the engine should be worked as easily as possible when traversing districts where there is danger of igniting a fire. The netting should be replaced with new when the terminal is reached.

Q. 4.—With a broken front, what should be done?

A.—This rarely happens. When it does it is usually the result of a blow, such as a collision, and as a rule is accompanied by other damages. A broken front should be repaired by replacing it with boards which can be held by the studs and nuts which were used to hold the front, as shown in Fig. 8. This, however, is but a temporary

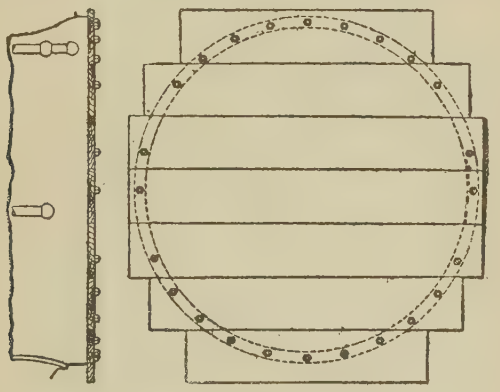


Fig. 8.
Broken Front Boarded.

makeshift, owing to the liability of the boards being burned by the heat and cinders of the smoke-box. However, it would serve until the terminal could be reached provided the engine worked easily.

Q. 5.—What are the probable causes when exhaust is apparently coming out of one side of stack?

A.—The exhaust nozzle may be set so high that

the steam could not properly fill the stack. Or, if either petticoat pipe or nozzle were out of line the same result would be effected.

Q. 6.—What would be the effect if the steam did not properly fill the stack?

A.—It would lower the steaming efficiency of the engine and the vacuum in the smokebox would be irregular in its formation and action, because the blast produces a partial vacuum in the smokebox by induction, just as a jet of steam in an injector lifts the water from a tank. If the jet does not fill the stack, the unfilled space permits a sluggish flow of the gases, resulting in the vacuum being lowered considerably. Hence it is important that there should be a proper adjustment of the size and position of the exhaust nozzle relatively to the height and diameter of the stack.

Q. 7.—If the grates are burned out or broken while on the road, what should be done?

A.—The burnt or broken grates should be blocked up with fish plates, brick or anything suitable that is available for the purpose. Would then disconnect the good grate immediately beyond the burnt or broken section so that the other grates would not be disturbed when the fire was shaken down.

Q. 8.—What should be done when the hopper of deep ash-pan is burned or broken in a drop grate?

A.—The fire should be pulled about three feet from the front of the remaining grates; then (if near a section house) the opening should be bridged over with a splice laid length-wise. If

unable to obtain a splice, anything available to serve the purpose may be used, because it would be impossible to proceed with the train any distance with the drop grate down. If a space the size of the drop grate were open, all the air that the exhaust draws would pass through it, and the fire on the remaining grates would not burn enough to maintain steam, even with a "light" engine.

CHAPTER VII.

VALVES AND VALVE GEAR.*

The different types of steam valves used on locomotives are the piston valve, the plain slide valve D shaped, and the balanced valve.

The plain slide valve is now but little used; it is D shaped, the flat under surface of the valve working back and forth over a flat surface containing ports and called the valve seat. A yoke attached to the valve rod surrounds the valve body and controls its motion back and forth across the valve seat, thereby regulating the admission and exhaust of steam to and from the cylinders. The body of the valve is hollow and has lips projecting out from its base. The objection to this valve is that the top of the valve is subject to whatever pressure is admitted to the steam chest through the throttle valve, causing it to ride heavily on the seat, and requiring more lubrication than a balanced valve, and also lessening the effectiveness of the engine. The balanced valve was designed to overcome these defects, and it also permits of a more free handling of the reverse lever.

There are two kinds of balance valves—the bal-

* For further particulars in regard to valves and valve gear the reader is referred to other volumes of "The Science of Railways" series relating to Locomotive Appliances and to Engineers and Firemen.

anced slide valve and the piston valve. The balanced slide valve is similar to the plain slide valve, with this addition: strips are fitted in the top of walled grooves around the top of the valves (a ring may be used instead of strips). In the bottom of these grooves arched flat springs are placed that crowd the strips against a plate fastened to the under side of the steam chest and called the pressure plate. These strips, when springs are in good order, prevent steam from passing in on top of valve and makes it as nearly a balanced valve as can be made with this type. A hole is drilled in the top of valve so that any steam that might leak in on top of the valve past the strips can escape. Otherwise pressure would accumulate and the balance feature of the valve would be destroyed.

The piston valve is the most perfect form of balanced valve. It is a spool shaped or cylinder shaped valve, with packing rings in the ends to make it tight in valve casing walls. If the inside packing ring should become broken the end of the cylinder at the end of the valve would receive too much steam and the engine would sound lame.

Q. 1.—What causes a valve to blow?

A.—The valve or valve seat may be cut or worn so that steam passes between the face of the valve and the valve seat and blows through the exhaust port out of the stack. This can only be remedied by facing the valve and seat. A spring may become weak or a strip broken, and cause a blow. A bridge between the exhaust or the admission

ports might be broken or have a hole, or a valve might become cocked and cause a blow.

Q. 2.—How would you test for a strip blow?

A.—Put the crank pin on the side where the blow is judged to be, on the forward center, and the reverse lever in the center notch on the quandrant. Open cylinder cocks. Move the reverse lever forward a little, but not enough to open port, and open throttle slightly. If it is a strip broken or a weak spring steam will enter the exhaust chamber of the valve and pass out of the rear cylinder cock. If the lever be moved slightly back of the center the steam will escape from the front cylinder cock. Care must be taken not to move the lever enough to open the ports. The steam coming from each cylinder cock alternately proves that the blow comes from above the valve and not under it. When a strip blows the valve and cylinder on that side will become dry, as the oil is blown away and wasted to a large extent.

Q. 3.—How can a cracked bridge or a hole in one be located?

A.—By examination and the fact that these defects would only cause a blow at one end of the stroke. A cracked valve or cut valve or seat will blow all the time.

Q. 4.—What could be done in case of a cocked valve?

A.—The lever should be jerked back and forth. If this does not seat it, the valve stem should be disconnected and the valve stem moved back and forth with a shaking motion. If this does not seat

valve the steam chest cover should be removed and the valve seated.

Q. 5.—How can a test be made for a piston packing blow?

A.—The engine should be placed so that side to be tested will have pin on top quarter. Steam should be given with brake set, when set steam will blow out of both cylinder cocks if piston packing blows.

Q. 6.—What should be done to repair an engine with a broken valve seat?

A.—It depends on the manner of the breakage. If a front port the valve should be placed so as to cover the back steam port and exhaust port. Would then disconnect and clamp valve stem. Take down main rod and block crosshead. The reason for taking down the main rod being that, steam having free admission to the front end of the cylinder, the engine on that side would be working against itself one-half of the time. For a broken back port the valve should be placed over the front steam port and exhaust port and then would proceed as if for a broken front steam port. Usually a broken valve seat will cause other damage to valve gear, such as broken or bent rocker arms, eccentric blades, or valve rods. These parts should be carefully examined before proceeding to move engine. In case a bridge is broken between a steam port and the exhaust port, ports should be covered with valve, then would disconnect valve rod and clamp it. The main rods should be left up. Care should be taken to see that no

pieces of the bridge have, by any chance, gone into the cylinder.

Q. 7.—What should be done in case of a broken valve?

A.—The steam chest cover taken up and broken parts of valve laid together to cover valve seat. If too badly broken a block should be used in place of the valve. Then steam chest cover should be replaced and fastened down. If a balanced valve, it would be necessary to use a block in place of the valve. If a piece of sheet iron or tin is available it could be used on top of valve seat.

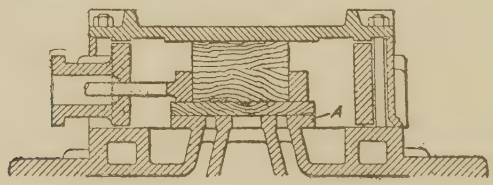


Fig. 9.
Ports Blocked with Valve Removed.

Q. 8.—When a slide valve breaks, what should be done to run the engine on one side?

A.—In the event it were a balanced valve, broken in such a manner that the ports could not be successfully covered, a heavy piece of sheet iron should be slipped in between the valve and valve seat and the valve blocked front and rear. Then the balance plate would come down solid on the valve, thus preventing breakage of the cylinder. If an ordinary slide valve, broken in the same manner, would first remove the valve, and then block with hardwood, the grain of which

should be crosswise of the seat. With the sheet iron over the seat and the chest filled with blocking so the cover would close down firmly upon it to make a steam-tight joint, the engine could proceed on one side without anything else but the valve rod being disturbed.

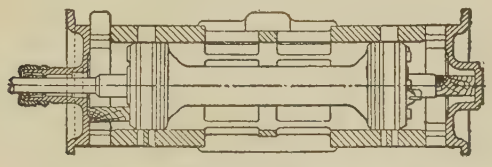


Fig. 10.
Piston Valve in Central Position Blocked with Wood at Each End.

Q. 9.—What should be done in the case of a broken steam chest wall or cover?

A.—If only a crack in the wall would take off steam chest casing, loosen nuts to studs near the crack, and wedge between studs and wall of steam chest. Tighten nuts and replace casing.

If chest or cover were badly broken steam would have to be shut out from the chest. This could be done by inserting a blind gasket in the joint in steam pipe in front end. If this could not be done, would block over steam ways in chest seat and hold in place with chest cover, perhaps using a piece of sheet iron or tin under the block. In going into front end to put in a blind gasket, would have fire as low as possible and lubricator and air pump shut off. But, as a rule, it would be better to prepare engine to be towed to terminal.

Q. 10.—How can a broken valve yoke be located?

A.—When a valve yoke breaks the valve re-

mains in front end of steam chest. Would move lever back and forth with cylinder cocks open. If yoke were broken steam would not come from forward cylinder cock.

To repair it, would take out relief valve cage and, if necessary, would shift valve by means of a small bar inserted where relief valve cage was taken out, and move engine off center on good side. Then would move valve to cover ports. Disconnect and clamp valve stem with inside end against valve. Put a plug against valve through relief valve cage hole and screw in cage to hold plug in position. If the valve yoke were only cracked would drop the lever down and work a light throttle. It would probably hold until reaching a terminal. Engine would be lame on that side.

Q. 11.—If a slide valve yoke or stem breaks inside the steam chest, how may the breakage be located?

A.—First it should be ascertained that the visible parts of the valve motion are intact and then the type of valve must be taken into account. If the valve stem or yoke is broken the valve is always forced forward to the end of the chest. If an outside admission piston valve or a slide valve, the lever should be placed in the forward gear and the steam observed as it leaves the cylinder cocks. Then the lever should be reversed and if the steam issues from both cocks on one side and from the back one only on the other side it would indicate that the latter has the disabled valve. If an inside admission valve the steam would issue from

the front and not from the back cylinder cock. If equipped with relief valves they should first be removed in order to watch the valve movement.

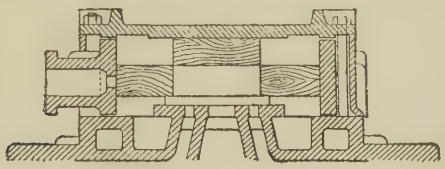


Fig. 11.
Valve with Broken Valve Stem Blocked.

Q. 12.—When a broken slide valve yoke or stem inside the steamchest has been located, what should be done to put the engine in safe running order?

A.—Provided relief valves are attached to the front end of the steam chest, the valve rod should be disconnected, then after forcing the valve to central position to cover the ports, the stem should be clamped from one end and blocked, by driving into the relief valve a plug, sufficiently long to hold the valve in place, then, leaving up the main rod, the engine may proceed. Should the relief valve be attached to the back end of the steam chest, the steam chest cover would not have to be taken up, but the back end of main rod would have to be disconnected and the crosshead blocked ahead. The disconnected valve rod would hold the valve against the forward end of the steam chest.

Q. 13.—If a valve rod breaks outside of steam chest, what should be done?

A.—Cover ports and clamp valve rod.

Q. 14.—If a cylinder head or piston head breaks what should be done?

A.—Disconnect valve stem. Cover ports and clamp valve rod.

Q. 15.—Should a main rod ordinarily be taken down?

A.—No, not unless damage to it or the connecting parts renders it necessary.

Q. 16.—What description of breakdown makes it necessary to take down the main rods or the side rods?

A.—The practice varies on different roads. In the case of modern engines of very heavy type it is practically impossible for two men to take down and load up a main rod. Therefore, when a main rod is left up, as is nearly always done on large engines, care should be taken to leave good openings in the cylinder, which should be well oiled. In the event a side rod is broken, or for any reason it must be taken down, it is necessary to take down the same rod on the opposite side; also the rods on both sides having knuckles in them should be removed, provided the next section of the side rod has been disabled.

Q. 17.—How could the cylinders be lubricated on the disabled side of an engine if the main rod is not taken down?

A.—If equipped with indicator plugs they should be removed and replaced after oiling through them. If not so equipped the valve should be shifted enough to show a little steam at the cylinder cocks, then oil with the lubricator.

Q. 18.—Is there any way to avoid stopping an

engine—that is, on one side—on the center, on the uninjured side?

A.—Yes, would release brake and reverse engine, open the throttle just before coming to a stop and good side would be on the quarter.

Q. 19.—What causes cylinder heads to break?

A.—In the case of a front head a broken rod strap, wrist pin, crosshead key, or a loose follower bolt. A broken main pin might break either head or anything in the guides might break the back head. Weakness of metal is always a cause for failure. With a broken front head, would cover ports and disconnect and clamp valve stem. If head were only cracked it could be braced by a block from head to pilot beam so it would hold until reaching a terminal where repairs are made. With a broken back head would cover ports and disconnect and clamp valve stem. Guides and main rods would have to come down, and the piston taken out of cylinder or fastened securely.

Fig. 12.
Port Blocked for Broken Cylinder Head.

Q. 20.—If a piston, crosshead, main rod or crank pin broke or became bent, what should be done?

A.—In the case of a broken piston or a bent piston rod both should be removed, the valve stem be disconnected and ports covered. For a broken

crosshead or bent or broken main rod, the main rod should be taken down and the piston pushed forward or backward, according to the type of engine, and the valve should be shifted so as to force steam against the piston in the direction in which it is wished to hold it. Then the valve should be clamped and the crosshead blocked as an additional precaution.

In the event of a broken crank pin it would not be necessary to take down the rod, because it could rest upon the yoke or guide. It should be first learned, in the case of a piston valve, whether it is an inside or outside admission because the two movements are exactly opposite.

Q. 21.—Where should a crosshead be blocked?

A.—At the rear of the guides. Less damage would then result if it got loose.

Q. 22.—What should be done in case of a broken valve stem or piston gland, or studs to glands broken?

A.—With metallic packing, would disconnect, cover ports and clamp valve stem.

Q. 23.—What should be done in case of a broken top or bottom rocker arm or link block pin?

A.—With top rocker arm, would cover ports, disconnect and clamp valve stem. With a lower rocker arm or link block pin, would cover ports, disconnect and clamp valve stem. Would push top rocker arm back and fasten it so that lower arm would clear links in case of broken link-block pin. In covering ports the front one could be left slightly open to help lubricate the cylinder, and the lubricator could be fed freely on that side. If

engine were equipped with indicator plugs in cylinder, would take them out and oil cylinder through these openings. If necessary, the cylinder head could be removed and the cylinder oiled that way, because main rods are too heavy to take down unless absolutely necessary.

Q. 24.—What should be done in case of a broken link hanger, saddle pin, tumbling shaft or tumbling shaft iron?

A.—Would put a block on top of link block to work engine about half stroke and put a short block under link block, allowing room for slip of link. With broken tumbling shaft it would be necessary to block both links. Would remove broken parts. To reverse engine would shift blocks from bottom to top of links. If one side only were disabled the good side could be reversed with lever. If an important train, some waste could be put on top of link and engine could then go on at a reduced rate of speed.

Q. 25.—How should a broken reach rod or reach-rod arm be repaired?

A.—Would block on top of link block with a block long enough to hold links at desired point of valve cut-off, with a short block under link block with space enough between block and link block to allow for slip of link. Would block but one link, with this type of breakdown, so as to allow for one link slipping up as the other slips down; if both links were blocked, damage would result to tumbling shafts. Blocks could be changed to reverse engine. A bar or a small timber could

be laid on top of frame and under lifting arms to link hangers instead of blocking link.

Q. 26.—What causes eccentrics to slip?

A.—Becoming hot, loose set screws, and dry valves. The latter may cause a broken eccentric or cam bolt, just as a hot eccentric may cause a broken strap.

Q. 27.—What causes hot eccentrics?

A.—Oil hole stopped up, no packing in oil cellar, plug gone out of bottom of eccentric strap, a strap lined too tight, or one so loose as to admit dirt freely between strap and eccentric.

Q. 28.—How should hot eccentrics be treated?

A.—Would open oil-hole, if stopped up. Would oil freely and often with valve oil. If the strap had recently been closed it might be too tight, in which case a thin liner in the strap jaws would help out. Would not put water on a hot eccentric.

Q. 29.—What indicates that an eccentric has slipped on an axle, and, when it is known which axle has slipped, how should it be reset?

A.—A lame exhaust indicates it, or in case of a bad slip one exhaust will entirely disappear; to determine which eccentric has slipped, the crosshead should be watched to find when the exhaust takes place. Having determined which eccentric has slipped, and in the event it were a go-ahead, the engine should be moved until the crosshead is very near to the end of its travel ahead. Then the eccentric should be moved around pointing in the opposite direction to the back-up, leaning either toward or from the pin, depending, of course, upon the style of the valve and whether

direct or indirect motion. Then directly steam appeared at the front cylinder cocks the set screws should be tightened. For a back-up eccentric the lever and crosshead would have to be placed in the opposite direction. The best way would be to mark the eccentric before starting, by placing the lever in forward notch and having crosshead at front end of travel. Then a mark should be made on crosshead and on the guide and the same done with the eccentrics and straps.

If, for any cause, an eccentric slips, and the engine is placed so that the mark on the crosshead corresponds with the mark on the guide, the marks on three of the eccentrics should correspond with the mark on the straps, while the mark upon the fourth or slipped eccentric should be some distance from the mark on its strap. By following this method an eccentric can be set absolutely true without guesswork.

Q. 30.—How would the exhaust sound with a slipped eccentric strap blade, or a loose eccentric strap bolt?

A.—It would sound as if out of square, or, the engine would go lame the same as with a slipped eccentric. When an engine goes suddenly lame, would not drop the lever down. It might be only a dry valve, or it might be something else. If it were something else the sudden change in the travel of the valve when the lever was dropped down would break something.

Q. 31.—How should a slipped eccentric blade be put back to its proper position?

A.—Usually there is a break in the grease and

dirt, where the blade enters the strap, which would serve to show where the blade should go. If not, would put engine on forward center on side that had slipped blade. Open cylinder cocks and the throttle lightly. Throw the reverse lever back and forth, and would note that if forward blade had slipped back, little or no steam would come out of front cylinder cock. If blade had slipped ahead it would blow strong out of front cylinder cock. Would reverse the lever and find that just the opposite condition prevailed. If there were too much admission at forward end of cylinder would shorten the blade; if too little, would lengthen it. The same procedure could be followed for the other motion eccentric.

Q. 32.—Which eccentric is most likely to slip?

A.—The eccentric most liable to slip is the forward motion eccentric when running forward and the back motion eccentric when running backward. because they are more nearly in line with the link block in either motion, and therefore, control the valve. It may be readily understood that when the engine is in full gear forward, the forward motion eccentric rod is nearly in line with the link block, the work of moving the valve being done by the forward motion eccentric; this proportion of work holds good in relation to the position of the link block in the link. Thus the back motion eccentric would be holding only the bottom of the link, the work done by the back motion eccentric being very light when the lever is in that position. When they slip on the axle they usually slip back, or away from the work.

Q. 33.—How should a slipped eccentric be set?

A.—Would put engine on forward center on disabled side. If it were the right forward eccentric, would put reverse lever in extreme back notch and mark valve stem at gland. Next would throw lever in extreme forward notch and move eccentric until mark on valve stem shows at gland. Would next tighten set screws. Would be careful to see that the throw followed the pin in that eccentric's motion. This is setting the slipped eccentric by the one that is not slipped. Or, would place the slipped eccentric with the throw at a right angle behind the pin and move it toward the pin enough to allow a little steam to escape from the front cylinder cock and then tighten set screws. This is setting an eccentric by the cylinder cock.

An engine might not be square after setting an eccentric in this manner, but it is as good as could be done without trams, and perhaps better than is sometimes done with them.

Q. 34.—How should repairs be made for a broken cam or cam bolt?

A.—Would take off broken parts. Disconnect on disabled side and cover ports. Clamp valve stem. If a cam bolt to a back-up eccentric that is not keyed on axle should break, would loosen set screws, oil freely between cam and axle and working the lever well down on the quandrant would go ahead with the train. A bolt may sometimes be found to use in case of a broken cam bolt, but if not, as a rule, it would be necessary to disconnect.

Q. 35.—What should be done in case of a broken eccentric strap?

A.—Would secure a longer bolt and fasten blade of broken strap to good eccentric strap. If this could not be done easily, would disconnect. In case it were done the engine should not be reversed.

CHAPTER VIII.

WALSCHAERT VALVE GEAR.*

The best place to begin is always at the beginning; and as the Walschaert valve motion, like any other device, is merely a development of some simpler form, it is necessary in studying it to start with the original form and trace the various steps in the development.

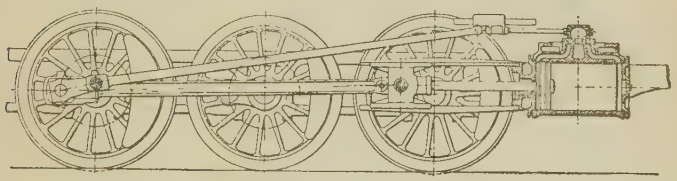


Fig. 13.

Fig. 13 represents the simplest form of valve motion; viz., a single eccentric of the return crank form, driving a plain normal valve without lap or lead by means of an eccentric rod directly connected to the valve stem. Assuming that the engine is to run forward, with the main pin on the

* C. O. Rogers, Traveling Engineer, American Locomotive Company.

For further particulars in regard to the Walschaert Valve Gear, including detailed instructions as to erecting and setting valves and examination questions and answers relating to its operation, the reader is referred to another volume of "The Science of Railways" series relating to Locomotive Appliances.

back center, as shown, the eccentric crank pin must be on the top quarter; in which case the valve will be in the central position on its seat with all ports closed. Although it is apparent that if the throttle were open this engine could not start of itself, with another engine of the same kind connected to the wheel on the other side of the axle, and with the main pins at right angles to each other, as is the case in the locomotive, the valve of the left hand engine would be in a position to admit steam behind the piston and start the wheels turning to the right. The eccentric crank on the engine which is shown would then move the valve forward, uncovering the back steam port and admitting steam behind the piston, and the engine would run forward. It is perfectly evident, however, that this engine will only run in one direction; for if, to start it backward, the wheel was pinched to the left, with the eccentric in the position as shown, the valve would be moved to the left and steam admitted ahead of the piston, forcing the crank pin back again to its position on the back center. In order to make the engine run backwards, the eccentric would have to be in the opposite position from that which it occupies, or on the lower quarter; in which case as the wheel was turned to the left or backward the eccentric would be a quarter of a revolution ahead of the main pin and move the valve forward, opening up the back port and admitting steam behind the piston as is necessary.

The first thing to do in the development of this simple form of engine, therefore, is to introduce some means by which it can be reversed. This

can be accomplished by introducing a beam between the eccentric and the valve stem, pivoted at its center so that one end moves with and in the same direction as the eccentric and the other end in exactly the opposite direction.

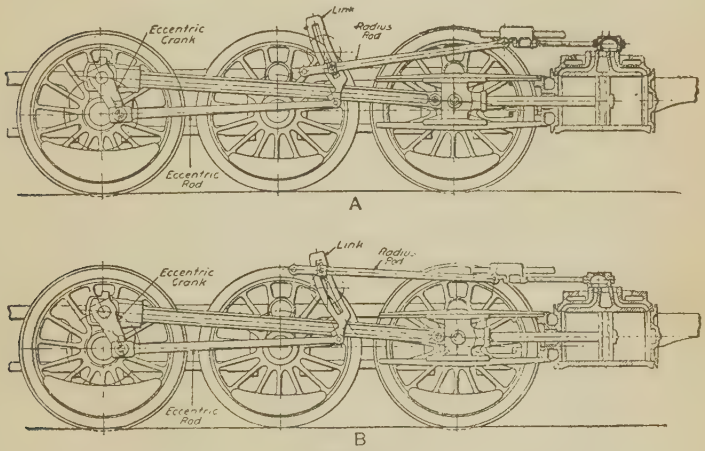


Fig. 14.

Such a construction is shown in Fig. 14. With the valve stem at the lower end of the link and the main pin on the upper quarter, as shown in diagram "A," the eccentric will have moved the valve to its extreme forward position and the back port will be opened for the admission of steam behind the piston and the engine will run forward. If, however, with the main pin and eccentric crank in the same position, the valve stem was connected to the upper end of the link, as shown in diagram "B," the valve would be moved to its extreme position to the left and the front port would be

opened and steam admitted ahead of the piston and the engine would run backward. With a flexible valve stem, or radius rod, connected to a block which slides in a curved slot in the beam, or link, as shown, and with the necessary mechanism for raising and lowering the block, it is evident that we now have an engine that can be reversed.

This engine, however, is still far from an efficient machine; for, as the valve does not close the port for the admission of steam until it is in its central position on the seat; and, as with the eccentric only a quarter of a revolution ahead of the main pin, it is not in this position until the main pin is on the center, whatever the travel of the valve, steam will be admitted to the cylinders throughout the full stroke of the piston, and the engine will use as much steam working against a light as against a heavy load. In order to govern the period for the admission of steam, or, in other words, give a variable cut-off, the valve must be redesigned so that it will close the steam port before it reaches its central position; that is, it must be given "lap," the lap of a valve being that portion of it which overlaps the steam ports when it is on its central position on the seat. But with lap given to the valve and also "lead," which is the width of the opening of the steam port given by the valve when the piston is at the beginning of its stroke, the valve motion must be so changed that the valve will be advanced from its central position on the seat a distance equal to the amount of the lap plus the lead, when the crank pin is on either of the centers.

It is apparent, from an examination of Fig. 15, that this advance of the valve can not be obtained by any change in the position of the eccentric crank relative to the main pin. Fig. 15 shows the

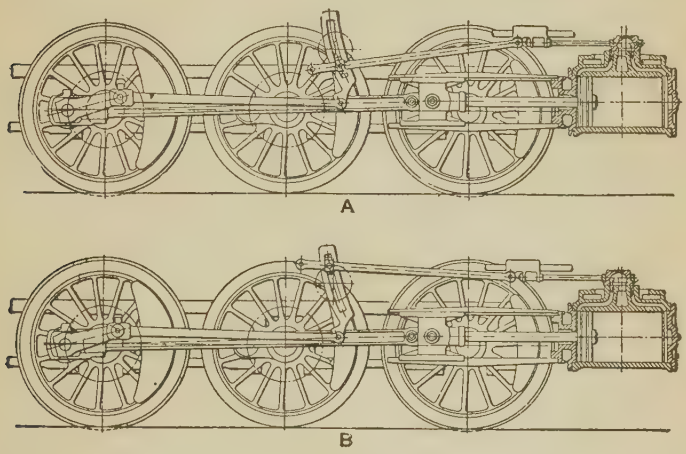


Fig. 15.

same valve motion as was shown in Fig. 14, except that the valve has one inch outside lap and the eccentric crank has been advanced to more than a quarter of a revolution ahead of the main pin. If then the link block is at the bottom of the link, as in position "A," the advance given to the eccentric will have moved the valve forward a distance equal to the lap plus the lead, and the back port will be opened for the admission of steam and the engine will run forward. If, on the other hand, the link block is moved to the upper end of the link, as shown in position "B," the advance given to the eccentric crank will have had the opposite ef-

fect and the front port will be opened and the reversibility of the engine thus destroyed. In order to provide lead, therefore, in any engine where there is but one eccentric, some means must be employed other than advancing or receding the position of that eccentric relative to the main pin; if there is to be any method of reversing the engine.

In the Walschaert valve gear the motion for providing lap and lead to the valve is derived from the main pin by suitable connections with the crosshead.

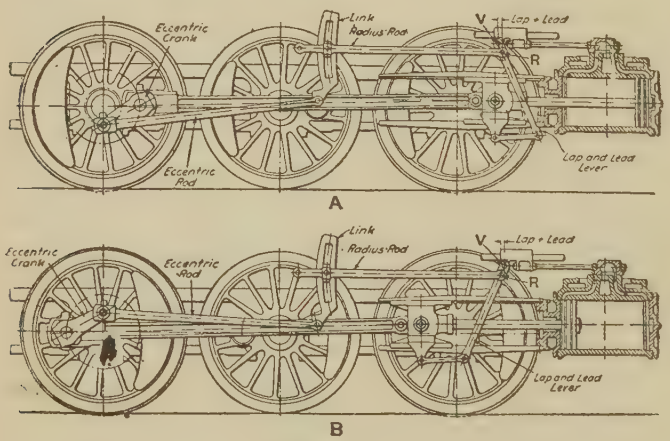


Fig. 16.

This brings us to the next step in the development of the Walschaert valve gear and the introduction of the lap and lead lever. Suppose that our link block is in the center of the link as shown in position "A," Fig. 16. As the center of the link block coincides with the center of the link support,

there will be no movement of the radius rod as the link swings back and forth through the action of the eccentric. If then the radius rod was connected with the lap and lead lever at the point "R," and the upper end of the lever was connected to the valve stem crosshead at "V," and the lower end to the crosshead arm by means of a short link, as shown, as this latter moves back and forth, the point "R" being fixed, the point "V" will rotate about it and the valve will be moved back and forth. With the main pin on the forward center, as shown in position "A," the angle assumed by the lap and lead lever has moved the valve back a sufficient distance to uncover the front port. With the main pin on the back center, as shown in position "B," the lap and lead lever is inclined in the opposite direction and the valve moved forward, and the back port is open. This is the way the Walschaert valve gear derives its lead. The distances between the connecting points of the lap and lead lever must be so proportioned that the travel of the crosshead from one end of the stroke to the other will give a travel to the valve equal to twice the lap plus the lead. That this lead is permanent and does not vary as the reverse lever is hooked up will be shown later on. The position of the eccentric crank relative to the main pin depends on which end of the link is used for forward motion. If the forward motion is taken from the bottom of the link, as is usually the case, the eccentric crank is a quarter of a revolution ahead of the main pin when the wheel is running forward, if the valves have outside admission; and a quarter of a revolu-

tion behind it, if the valves have inside admission. If the top of the link is used for forward motion, the eccentric crank is a quarter of a revolution behind the main pin, if the valves have outside admission; and a quarter of a revolution ahead of it, if the valves have inside admission. In all cases, if the valves have outside admission, the radius rod is connected to the lap and lead lever below the valve stem, and above it, if the valves have inside admission.

The simple form of direct valve motion, shown in the Fig. 13, has now been so modified that the engine is reversible and has a variable cut-off. It only remains to provide the necessary reversing mechanism and we have the Walschaert valve gear in its complete form as shown in Fig. 17, which represents its application to a consolidation engine.

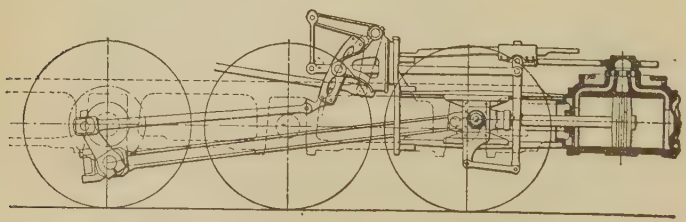


Fig. 17.

Figure 18 shows a general outline of the gear as arranged for inside admission valves on which are given the names of the various parts as recommended by the American Railway Master Mechanics' Association. Starting at the crank pin, we have the eccentric crank, eccentric rod, link, reach

rod, lift shaft, radius rod hanger, radius rod, lap and lead lever, lap and lead lever connector, and crosshead arm.

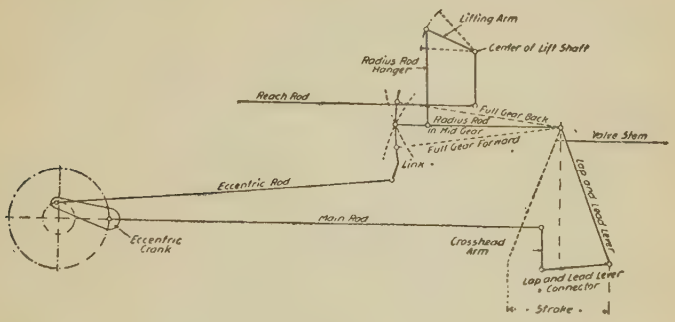


Fig. 18.

Having studied the functions of the different parts of the Walschaert valve gear, it remains to trace the movement of the valve through a complete revolution of the wheel. Figs. 19, 20, 21 and 22 show a series of diagrams representing different positions of the valve for different positions of the crank pin. For the sake of simplicity, the valve and cylinder are shown in section, while the other parts of the gear are represented by their center lines and center points only. As will be apparent, these diagrams are out of proportion, the valve and the eccentric throw having been enlarged in order to bring out more clearly the position of the edges of the valve relative to the edges of the cylinder ports. In Fig. 19, the valve is outside admission and the motion is represented as being in full forward gear; or with the reverse lever in the extreme forward position. Fig. 20

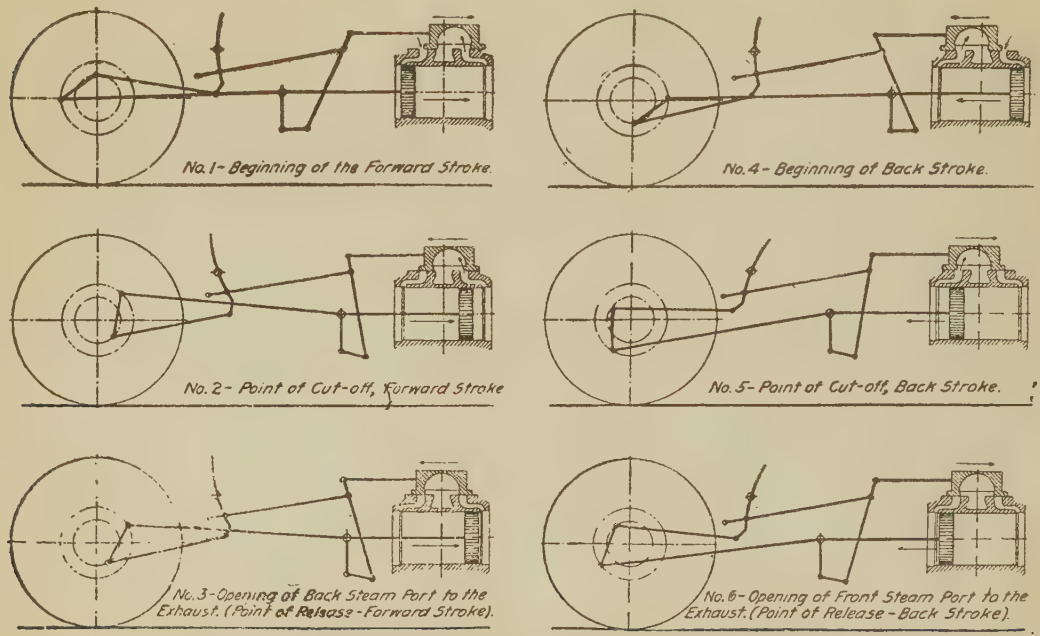

No. 1 - Beginning of the Forward Stroke.
No. 4 - Beginning of Back Stroke.
No. 2 - Point of Cut-off, Forward Stroke
No. 5 - Point of Cut-off, Back Stroke.
No. 3 - Opening of Back Steam Port to the Exhaust. (Point of Release - Forward Stroke).
No. 6 - Opening of Front Steam Port to the Exhaust. (Point of Release - Back Stroke).

Fig. 19.

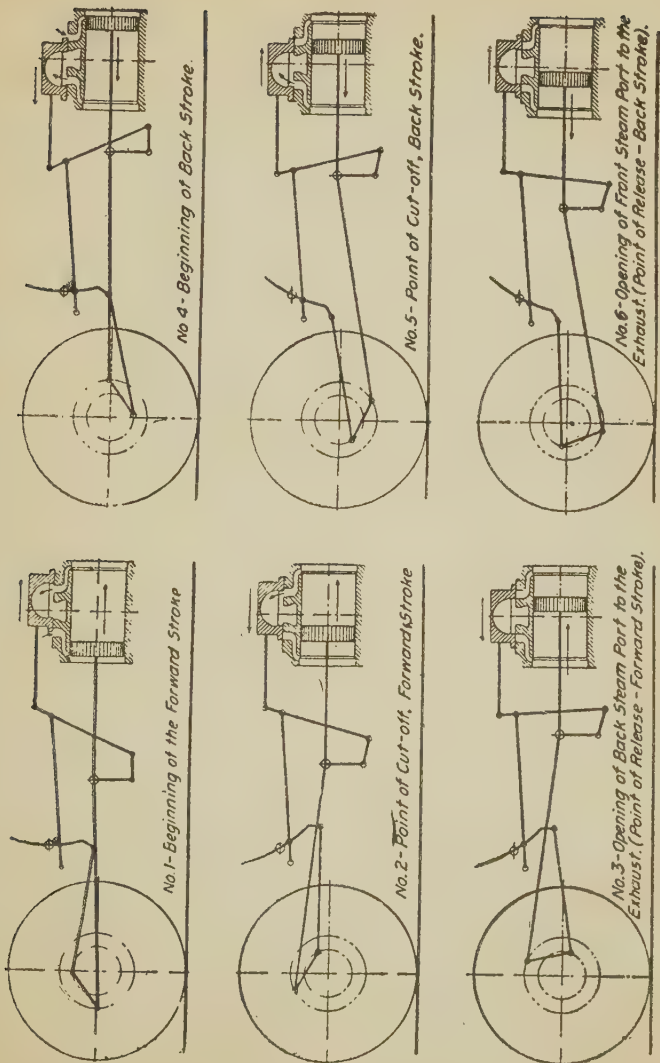

No. 1 - Beginning of the Forward Stroke
No. 2 - Point of Cut-off, Forward Stroke
No. 3 - Opening of Back Steam Port to the Exhaust. (Point of Release - Forward Stroke).
No. 4 - Beginning of Back Stroke.
No. 5 - Point of Cut-off, Back Stroke.
No. 6 - Opening of Front Steam Port to the Exhaust. (Point of Release - Back Stroke).

Fig. 20.

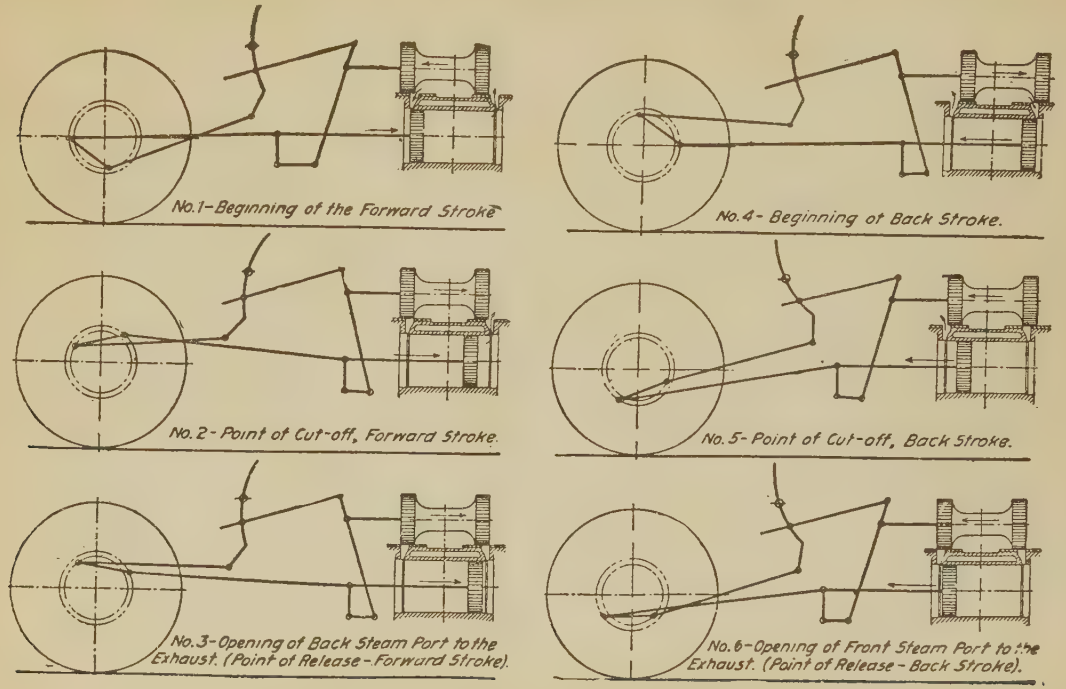

No. 1- Beginning of the Forward Stroke
No. 4- Beginning of Back Stroke.
No. 2- Point of Cut-off, Forward Stroke.
No. 5- Point of Cut-off, Back Stroke.
No. 3- Opening of Back Steam Port to the Exhaust. (Point of Release - Forward Stroke).
No. 6- Opening of Front Steam Port to the Exhaust. (Point of Release - Back Stroke).

Fig. 21.

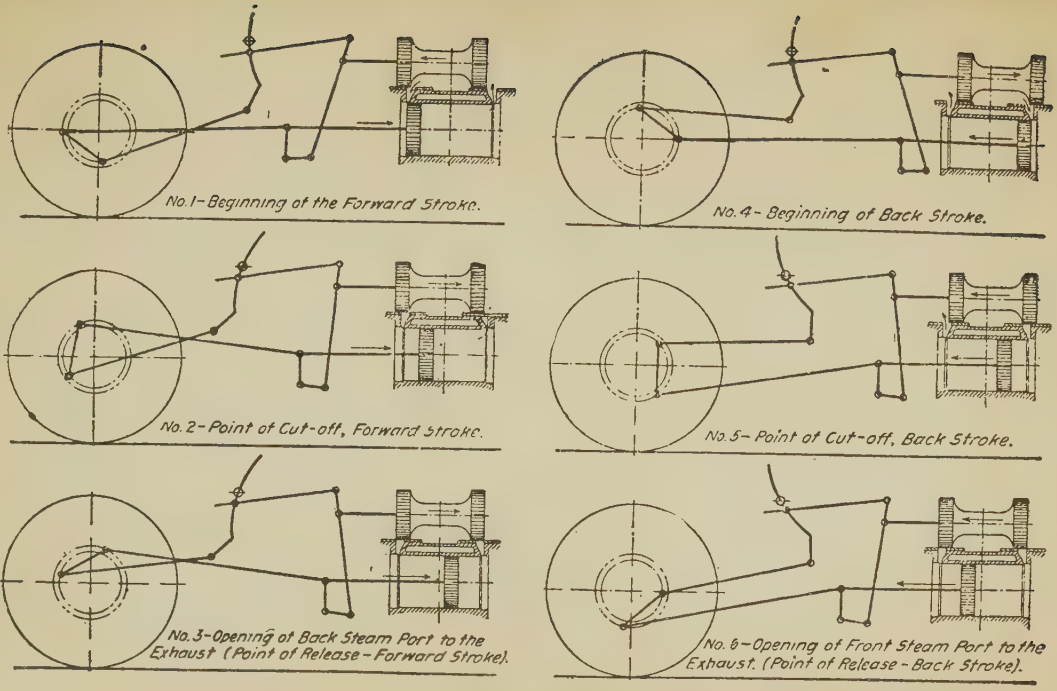

No. 1 - Beginning of the Forward Stroke.
No. 4 - Beginning of Back Stroke.
No. 2 - Point of Cut-off, Forward Stroke.
No. 5 - Point of Cut-off, Back Stroke.
No. 3 - Opening of Back Steam Port to the Exhaust (Point of Release - Forward Stroke).
No. 6 - Opening of Front Steam Port to the Exhaust. (Point of Release - Back Stroke).

Fig. 22.

represents the same valve motion, but in this case the reverse lever is hooked up and the link block is nearer the center of the link and the engine is cutting off at about 25 per cent. of the stroke. Figs. 21 and 22 represent a valve motion as arranged for an inside admission piston valve; in Fig. 21, the motion being in full gear forward; while in Fig. 22 it is represented with the reverse lever hooked up.

As has already been shown, the valve receives its motion from two distinct sources; first, from the eccentric crank which gives the long travel to the valve; and second, from the crosshead by means of the lap and lead lever, which would give a short travel to the valve even if the eccentric rod was disconnected.

Starting with diagram 1, Fig. 19, as the valve is outside admission, with the main pin on the back center, the eccentric crank is on the top quarter, or a quarter of a revolution ahead of the pin, and the radius rod is connected to the lap and lead lever below the valve stem. The link is in its central position, and the valve would be in its central position on the seat, if it were not for the motion given to it by the lap and lead lever. As it is, however, the crosshead being at the back end of the stroke, the lower end of the lap and lead lever is at its extreme back position and the angle assumed by the lever has moved the valve forward, as indicated by the arrow, a distance equal to the lap of the valve plus the lead. Going to diagram 1, in Fig. 20, the main pin, eccentric crank and crosshead are in the same position as they were in the corres-

ponding diagram in Fig. 19; and the link is in its central position. Thus, although the link block is nearer the center of the link, the radius of the link being equal to the length of the radius rod, the front end of the radius rod is the same horizontal distance from the center of the crosshead as it is in diagram 1, Fig. 19; consequently the angle assumed by the lap and lead lever is the same and the valve has been moved forward the same distance from its central position, and the lead is the same as it is with the reverse lever in full gear.

In Figs. 21 and 22, diagram 1 in each case represents the position of the valve at the beginning of the forward stroke; the same as the corresponding diagrams in Figs. 19 and 20. As the valves are inside admission, however, the radius rod is connected to the lap and lead lever above the valve stem. The valve, in each case, has thus been moved back, instead of forward, by the movement of the lap and lead lever; and the back port is open to the live steam and the front port to the exhaust.

Going back to Fig. 19; in diagram 2, the piston has moved forward a distance equal to about 85 per cent. of the stroke; the valve has traveled to its extreme forward position and back again, as indicated by the arrow, till it has just closed the back steam port; while the front port is still open to the exhaust. In other words, the valve is at the point of cut-off. In diagram 3, the piston has moved still nearer to the forward end of the stroke. The exhaust edge of the valve is now in line with the edge of the back steam port;

so that any further movement will open communication with this port and the exhaust. The front port, on the other hand, has been closed to the exhaust and whatever steam is ahead of the piston will be compressed. In diagram 4, the piston is at the extreme forward end of the stroke; the angle assumed by the lap and lead lever has moved the valve back a distance equal to the lap plus the lead; the front port is open for the admission of steam and the back port is open to the exhaust. In diagram 5, the piston is moving toward the back end of the cylinder and the valve has just closed the front port to the admission of steam, showing the cut-off position of the valve on the back stroke. In diagram 6, the piston is very nearly at the end of the back stroke and the valve is about to open the front port to the exhaust; while the back port is closed to the exhaust and compression is taking place in the back end of the cylinder.

As the diagrams in Figs. 20, 21 and 22 represent the same valve events as the corresponding diagrams in Fig. 19; it will not be necessary to examine them separately. It will be noticed that in Figs. 20 and 22 the valve cuts off the steam from the cylinders and opens the steam ports to the exhaust at a much earlier period in both the forward and back stroke than it does in Figs. 19 and 21, which shows the effect of hooking up the reverse lever.

These diagrams show very plainly the difference in the arrangement of the Walschaert valve gear for outside and inside admission valves, also the

fact that the lead of the valve is the same for all cut-offs.

To change the lead of the Walschaert valve gear, it is necessary to either change the lap of the valve, reducing it to increase the lead and increasing it to reduce the lead, in which case the cut-offs will occur at later or earlier periods in the stroke, respectively; or to change the lengths of the arms or distances between the connecting points of the

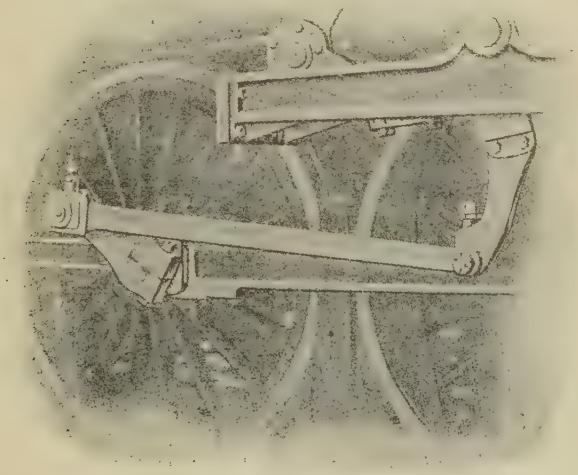


Fig. 23.

lap and lead lever. Increasing the distance between the radius rod connection and the valve stem connection to the lap and lead lever would increase the lead; or shortening this distance would decrease the lead.

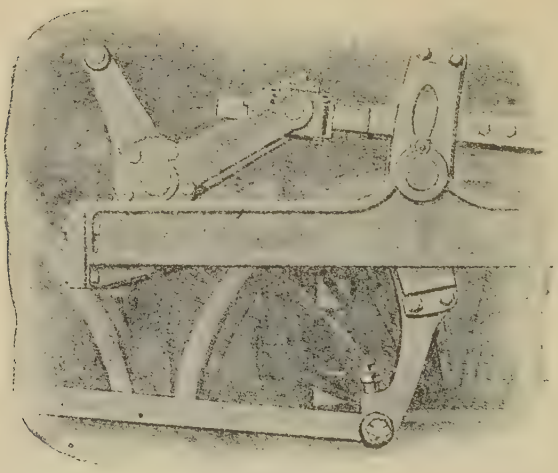


Fig. 24.

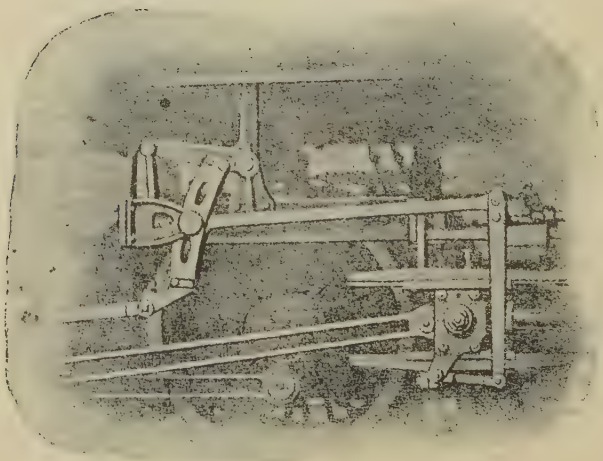


Fig. 25.

Just here it might be of interest to study some of the ordinary forms of construction of the various parts of the gear.

In Fig. 23 are shown an eccentric crank and eccentric rod. The eccentric crank, as will be seen, is secured to the extension of the main crank pin by a binding bolt. The crank is split so that it can be drawn to a tight bearing by means of the bolt. This bolt, together with a key, keeps the eccentric crank fixed in its position on the main pin. By driving out the binding bolt, the eccentric crank may be taken off if necessary. This construction permits of using a solid bushing on the side rod at the main crank pin.

The link and reverse shaft are shown in Fig. 24, In this design of gear, the radius rod is directly connected to the lift shaft arm by means of a slip block, which makes a very simple arrangement.

Fig. 25 shows another style of reversing mechanism. In this design, the backward extending arm of the lift shaft is connected to the back end of the radius rod by means of a link.

In Fig. 26 are shown the parts of the Walschaert valve gear connecting the valve stem and the crosshead. It will be noticed that the radius rod connection with the lap and lead lever is above the valve stem connection, showing that the valve is inside admission.

BREAKDOWNS WITH WALSCHAERT VALVE GEAR.

Having considered the principles of the Walschaert valve motion, the next phase of the subject to take up, and that which is of most interest

to all engineers, is—what may be done in case of a breakdown. It would be impossible to lay down rules to cover every case that might arise; but we can take up some of the more usual or most possible failures and consider the best and quickest course to follow in such cases.

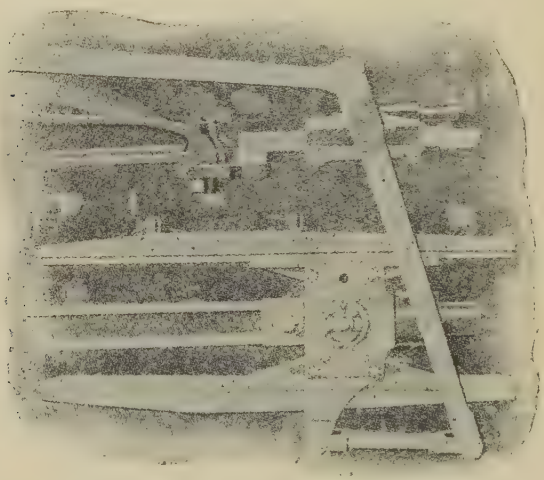


Fig. 26.

Suppose, for instance, an eccentric crank, eccentric rod, or the foot of the link is broken; or one of the link trunnions twisted off, the other trunnion holding the link in position. In such cases, take down the eccentric rod, disconnect the back end of the radius rod from the lift shaft arm and secure the link block in the center of the link. With the motion disconnected and blocked in this way, the valve on the lame side receives a travel from the lap and lead lever equal to twice the amount of

the lap plus the lead, which gives a port opening equal to the amount of the lead. This permits of leaving the main rod up and running in with both sides; as the cylinders can be lubricated and, though the cut-off will be very short on the disabled side, the steam that is admitted will do a certain amount of work and the engine can be reversed.

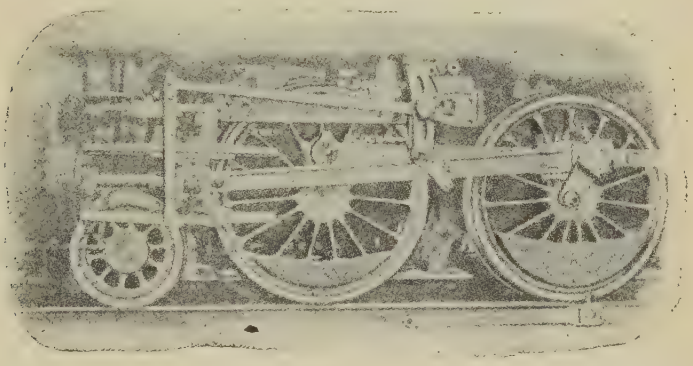


Fig. 27.

Fig. 27 shows an engine with the valve gear disconnected and blocked as just described. In the design illustrated, the radius rod is connected to the lift shaft arm by means of a radius rod hanger so that it can be readily disconnected by taking out the pin connecting the radius rod hanger and the lift shaft arm. The link block is secured in the center of the link by means of two blocks shown, one placed below and the other above the link block and securely wedged in position.

With the link block secured in the center of the link, care must be taken in making a stop that the

main pin on the lame side is not on either quarter; as, in this case, the lap and lead lever would be in a perpendicular position, as shown in the illustration, and the valve would be central on the seat; and, as the pin on the other side would be on the dead center, it would be impossible to move the engine.

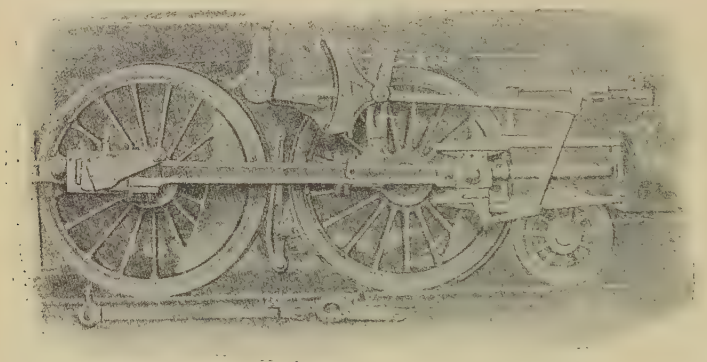


Fig. 28.

In some arrangements of the Walschaert valve gear, the radius rod is directly connected to the lift shaft arm by means of a slip block or cross-head. It is common practice in such cases to make the lift shaft arm in two pieces so that the radius rod may be easily disconnected from it, as shown in Fig. 28. Remove the outer section of the lift shaft arm, take off the cap of the slip block, lift out the end of the radius rod and remove the slip block. The parts that it is necessary to take down are shown in the foreground. The link block is secured in the center of the link in the same way as in the previous case.

So far, we have not considered any accidents which would require blocking the valve to cover the ports. In all cases where this is necessary, if the engine has no relief valves in the cylinder heads to remove, it is good practice to take down the main rod on the disabled side.

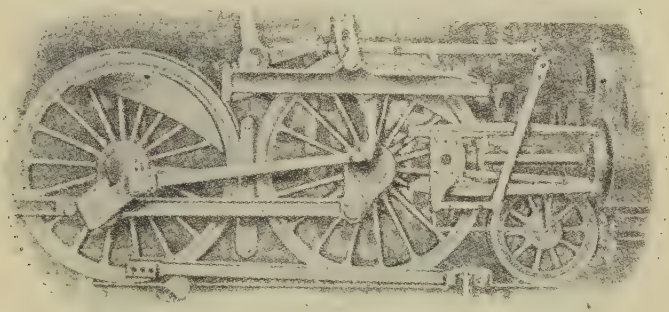


Fig. 28a.

Suppose, for instance, the main rod was broken, or the piston rod bent, or a cylinder head knocked out. In any of these cases, if the valve has inside admission and there are no relief valves in the cylinder heads, the engine may be disconnected and blocked, as shown in Fig. 28a. Disconnect the front of the radius rod from the lap and lead lever and suspend it clear of the latter by means of a wire or chain from some convenient support. Secure the valve to cover the ports. This can usually be done by means of the set screw provided in the valve stem crosshead for this purpose; but, if there is no such set screw, the valve stem crosshead may be blocked. Take down the main rod

and block the crosshead at the back end of the guides, as shown. With the valve motion disconnected in this way, the reverse lever is free to operate the other side and the engine can be run in on one side. If the crosshead arm, lap and lead lever connector, or lap and lead lever is broken, the engine might be blocked in the same way as illustrated in Fig. 28a; except that, of course, such of the broken parts should be removed as would in any way interfere with the running of the engine.

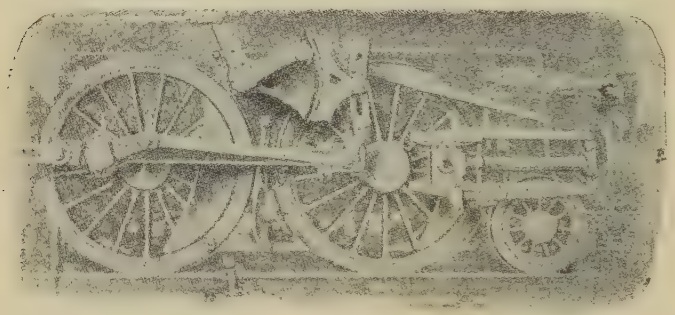


Fig. 28b.

If the valves have outside admission and there are no relief valves in the cylinder heads, in cases where it is necessary to secure the valve to cover the ports such as have been considered, the engine might be disconnected as shown in Fig. 28b. Disconnect the radius rod from the lap and lead lever and take down the latter, as, otherwise, the front end of the radius rod would strike the lever as the radius rod moves back and forth to the motion of the link. Suspend the front end of the radius rod

from the valve stem crosshead guide, using for this purpose a wire or chain (the fire door chain if no other is at hand). Secure the valve to cover the ports and take down the main rod and block the crosshead at the back end of the guide.

If the engine has cylinder relief valves and the main rod and piston on the disabled side are in condition to run, the main rod may be left up when the valve is secured to cover the ports. In that event, remove the relief valve from the cylinder heads to relieve compression and also permit of lubricating the cylinder.

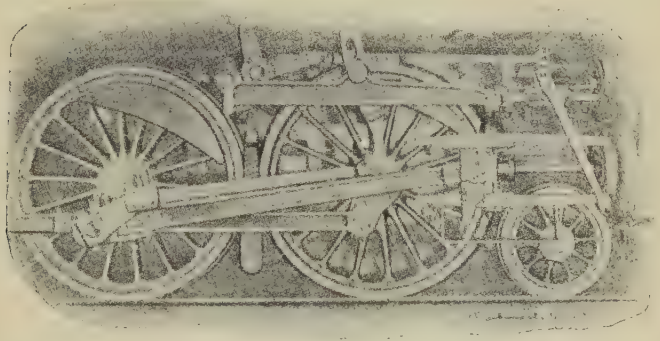


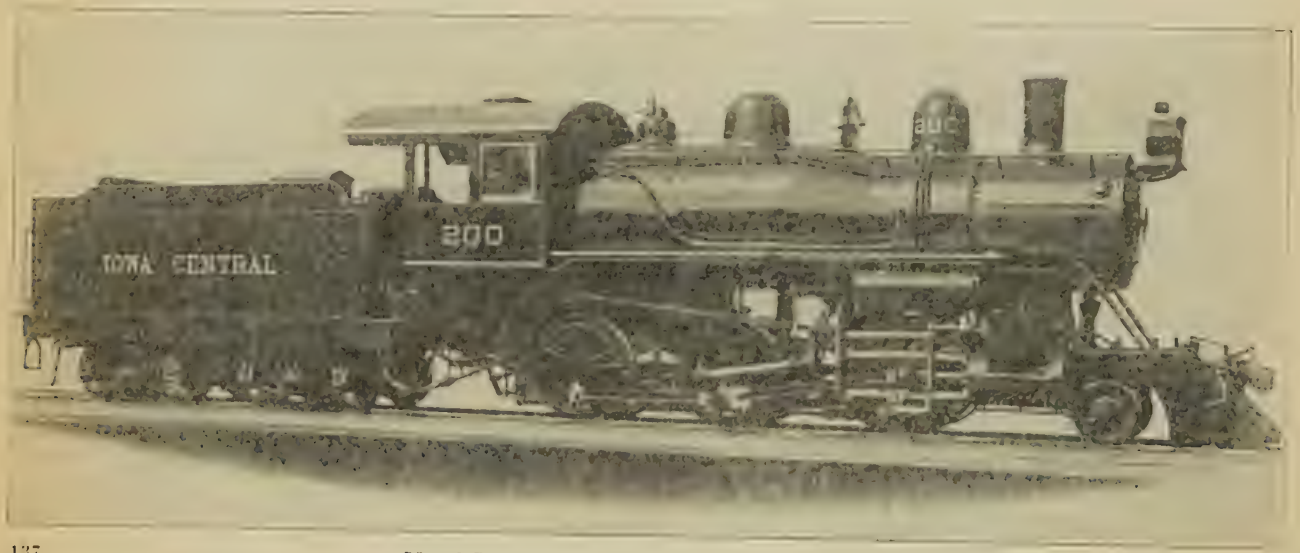
Fig. 28c.

Suppose, for instance, the lap and lead lever, lap and lead lever connector, or crosshead arm were broken; an engine with inside admission valves and relief valves in the cylinder heads could be blocked, as shown in Fig. 28c. Disconnect the radius rod from the lap and lead lever and suspend it clear of the latter, as shown. Secure the valves to cover the ports. Tie the lower end of the lap and lead lever ahead by means of a rope

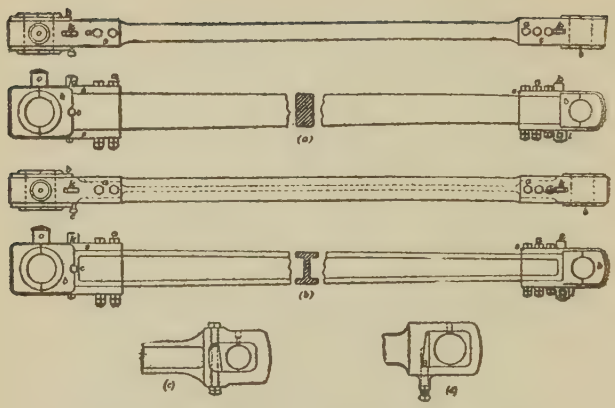
secured to the cylinder cocks. Take out the relief valves, as previously recommended. The engine can then be run in on one side.

If the valves were outside admission, under the same conditions as assumed in the case illustrated in Fig. 28c, the main rod could be left up and the engine disconnected in the same way; except that the lap and lead lever would have to be taken down in order to clear the radius rod.

We have not attempted to enumerate all the accidents that might occur on the road; but we trust that the explanation of what may be done in the cases considered will assist the engineer to meet any troubles that might possibly happen to the Walschaert valve motion.

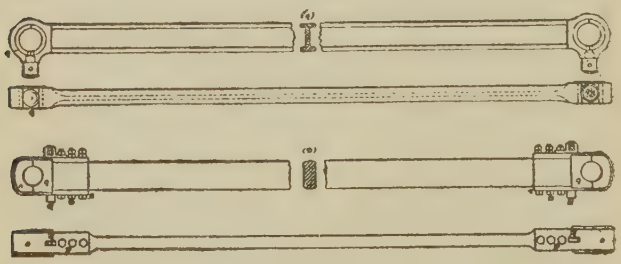


Mogul Locomotive with Walschaert Valve Gear.



TYPES OF MAIN RODS.

(a)-Rectangular cross-section type; (b)-I-cross-section type; bb, Brasses; ss, Straps; kk, Keys for adjusting brasses; cc, Set screws—and ll, Guards—securing keys in position; oo, Oil-cup.



TYPES OF SIDE RODS.

(a)-Rectangular cross-section type, with strap ends; (d)-I-cross-section type, with solid ends; kk, Keys for taking up wear of brasses in strap-end type; no provision made for this in solid-end type, but worn brasses must be replaced by new ones.

CHAPTER IX.

GUIDES AND RODS.

The crosshead is the medium of connection between the piston rod and the main rod, by means of which the pressure exerted on the piston head by the steam is transmitted to the crank pin of the main driving wheels.

The main rod cannot be connected directly to the piston rod because the strain on the piston rod, stuffing box and packing gland would be too great. To overcome this the crosshead working in guide bars is employed.

The crosshead at piston end has a horizontal tapering socket at this end, through which a tapering key-way is cut at right angles perpendicularly to the socket. This socket receives the tapering end of the piston rod and a key is driven in the key-way which draws and holds the piston rod firmly in the crosshead.

If this key becomes loosened or broken, or the piston rod breaks, it results in a bad pound. If the piston rod or key were to break the front cylinder head would be destroyed, and it would be necessary to disconnect the valve stem and cover ports.

The main rod end of the crosshead is equipped with a wrist pin extending across the extended

sides of the crosshead. The forward end of the main rod is connected to this wrist pin by a strap and bolts holding brasses that fit around the wrist pin and are adjusted by means of a tapering key, which is held tight by means of a set screw through a keeper at the bottom of the strap. If this key is not properly adjusted a pound results that may cause a broken rod strap and other consequent damage.

Q. 1.—In case of a broken wrist pin, front end strap to main rod or crosshead, what should be done?

A.—Would take down the main rod and such other parts as breakage made necessary, block crosshead back in guides (because front cylinder head is more easily and cheaply replaced in case of damage from crosshead getting loose in guides through blocking working loose), disconnect valve stem and cover ports.

Q. 2.—In the event that either a link lifter or arm or the reverse lever or reach rod broke, what should be done?

A.—The same as for a broken link saddle pin.

Q. 3.—If the reverse lever or reach rod were caught at short cut-off by a broken spring or hanger, how could the engine be moved?

A.—By disconnecting the tumbling shaft arm and blocking over the link block pin with blocking that would allow sufficient power to be used to start the train.

Q. 4.—What should be done in case of a broken main rod?

A.—Would take off broken parts. Block cross-

head, disconnect valve stem and cover ports.

Q. 5.—Why is it necessary to keep rod brasses keyed up properly?

A.—To avoid their pounding. A pounding brass will heat the same as one keyed too tight.

Q. 6.—Should a rod key be slackened if a pin runs hot?

A.—No, not unless it has been recently keyed and is found to be keyed too tight. Would look for the trouble from some other source.

Q. 7.—How can it be determined if there is a pound in rod brasses or a driving box?

A.—Would put engine on quarter on side to be tried, have fireman give cylinders a little steam, then would throw lever back and forth, "chug" her, it is termed. A pound could readily be found by this means. Would not key brasses so they could not yield a bit under "chugging," or there would be a hot pin.

Q. 8.—What should be done in case of a broken side rod or crank pin?

A.—Would take down side rods on both sides on an eight-wheel engine, and if a main pin, the main rod on that side would have to come down.

Q. 9.—Why must the opposite side rod come down?

A.—Because with nothing to guide it when it reaches the center it is as apt to go up as down, in the wrong direction instead of the right, and then there would be more damage. On consolidated engines, if rod in front or back section were to break, would take down the same rod on the opposite side, because they have the same relation

to each other as the side rods of an eight-wheel engine. If in middle section all side rods would have to come down. On six-wheel conected engines, if back side rod were to break would take down back side rods. If a front side rod broke all side rods would have to come down, because knuckle joint back of pin would turn with crank pin and without rest of side rod.

Q. 10.—If a lower rocker arm or if a link pin were to break, how should the engine be disconnected?

A.—In the event it were a lower rocker arm, all that would be necessary, unless the link interfered, would be to remove the broken part of the arm and cover the ports by placing the valve in its central position and leave the main rod up; otherwise it would be necessary to take down the eccentric straps and rods. If a link pin were broken there would be more or less danger of interference between the link and rocker arm, so the eccentric straps and rods only should be taken down and the ports covered.

CHAPTER X.

FRAMES AND TRUCKS.

Q. 1.—What is the reason more right than left locomotive frames break on right lead engines?

A.—There are several causes — poor design, welds, or material, or water in cylinders. When the right side leads, the engine always pounds harder on the right than on the left side, because when the right crank pin passes the forward center the left cylinder is pulling forward. This helps the right cylinder in pushing the right box back against the jaw of the pedestal, and the same result occurs on the back center on the left side. This is usually the cause of more right frames breaking than left frames on right lead engines. To have the left engine lead would merely transfer the trouble from one side to the other. Broken frames may be avoided by keeping the thimble bolts tight and the wedges set up.

Q. 2.—If a frame breaks between the main driver and cylinder, what should be done?

A.—It is safest to be towed in dead, otherwise would disconnect the disabled side and take engine in light.

Q. 3.—If the frame broke back of the main driver, what should be done?

A.—(1) The side rods on both sides back of the

main driver should be taken down, then proceed. (2) The valve stem on disabled side should be disconnected, the ports covered and the main rod left up. The engine should proceed "light" with the good side. If it is a consolidation engine and the break is behind the main driver, the side-rods on the rear section only should be taken down. If a mogul type with the knuckle pin on the forward section of the side-rod, all side rods should be taken down.

An engine disconnected on one side for a broken frame should not be worked harder than necessary to propel it "light" to the shop, because, if an attempt is made to pull a train with one side broken the other side will soon break in the same manner. So great is the risk of this occurring that it is considered good practice to have the engine "towed in" if possible.

It will be observed that every time steam goes in between the back head and the piston the break opens, closing again when the steam is between the front head and the piston. This is apparent even when using only enough steam to run the engine "light." This constant strain on the good side is doubtless often the starting point of another break.

Q. 4.—If an engine truck wheel or axle breaks, what should be done?

A.—It should be removed entirely or else be blocked up so as to have the wheel clear of the rail, and the truck frame should be fastened securely to the engine frame with chains. The

same should be done in the event of a tender truck wheel or axle breaking; the truck frame should be fastened with chains to the tender frame. Then the engine should be taken slowly and cautiously to a point where repairs may be made.

Q. 5.—If an engine truck spring or equalizer or a tender truck spring were to break, how should the engine be blocked?

A.—The truck frame should be allowed to ride on the boxes, if the pilot would not be too low; otherwise would block between the top of the boxes and the truck frame. Blocking for a broken tender spring varies according to the type of truck. Some have a coil spring over each axle box and are easily taken care of; some have semi-elliptic springs with the spring band against the frame and the ends of the spring resting on the arch bar over the axle boxes, while others have elliptic or coil springs supporting the truck bolster and resting on the sand plank. It is necessary to block over each individual box with the first; between the truck bolster and the tender frame, with the second, and for the third between the truck bolster and the plank.

Q. 6.—If a tender truck breaks, what should be done?

A.—Should the forward truck break would remove it and would chain the front end of the tender frame to the rear end of the engine frame. If a rear truck, it could be replaced with a car truck, if one were available. Or, the tender could

be jacked up and the front truck put at the rear, and the front end chained to the engine frame as described. When a tender has been chained in this manner, would proceed cautiously and run the engine slowly.

CHAPTER XI.

TIRES, WHEELS AND AXLES.

Q. 1.—If a forward, main, intermediate, back or trailer tire breaks, what should be done in order to take engine in?

A.—Would run the wheel on a wedge so as to clear the rail under all conditions, remove the oil cellar and fit a block in its place. Then would

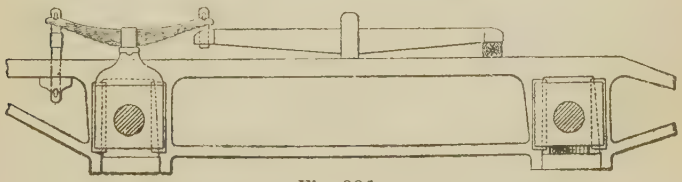


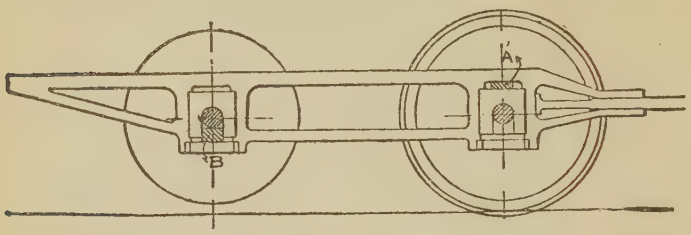
Fig. 28d.
Axle Blocked for Broken Driving Wheel.

place another block between the bottom of the box and the pedestal binder, and block under the equalizers nearest the disabled wheel to take the weight off the ground.

Q. 2.—What should be done if a front tire on a ten-wheel engine breaks?

A.—If the side or main rods were damaged too badly to be left on, would take down the side-rods on the good side and run the engine with one side coupled to the main pin only.

In order to put the wheel in shape to be run in without doing further damage, would run it on a wedge about five inches thick, remove the oil

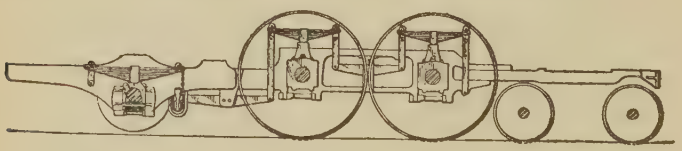


BROKEN BACK TIRE ON EIGHT-WHEELER

A—Block between box and frame. B—Block under journal.

Fig. 29.

cellar, fit a block in its place, and fill all the space between the bottom of the driving box and the top of the pedestal brace with another block.



How to Handle a Broken Trailer Tire or Broken Trailer Equalizer.

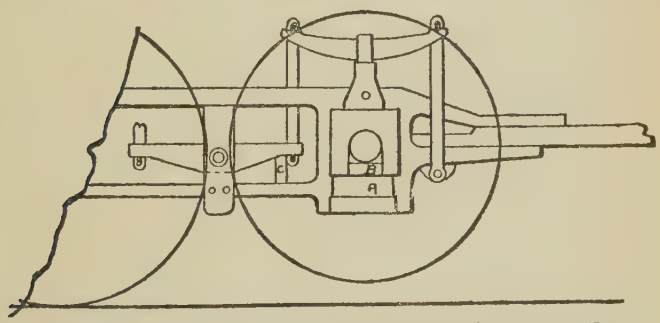
Fig. 30.

Q. 3.—What should be done if a back wheel breaks off its axle?

A.—Would remove both the side-rods between the main and back pair of wheels and, if necessary, all the side-rods also. Put a jack under the axles to raise the broken end, remove the oil cellar

and fit a hardwood block between the axle and the pedestal brace or binder on the disabled side and block under the spring saddles. Would keep the good wheel on the rail and block on top of its box and drive wedges between the drawbar and the chafing iron and block on top of both the main boxes. Would then run engine "light" with great care.

Should the axle break between the two driving boxes, would, if possible, remove both wheels. If they could not be removed would block them up high enough to clear the rail. If a heavy engine, would transfer part of its weight to the tender and block between the equalizer and the engine



METHOD OF BLOCKING FOR BROKEN FRONT TIRE ON TEN WHEELER

A—Is the block between bottom of box and pedestal brace. B—Is the wooden block in place of the cellar. C—Is the block under equalizer

Fig. 31.

truck frame on both sides. Would then raise the back end of engine and block top of both main boxes and put wedges between the drawbar and the chafing iron. Should this be impracticable the engine could be run in "light," but would in-

sert a short piece of rail in the fire-box door, chain to the draw-bar and block up under the back end of the rail on the tender. If the latter method were followed the engine should be "towed in."

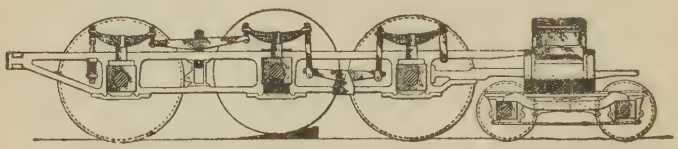


Fig. 32.
Method of Raising and Blocking Wheel for Broken Tire.

Q. 4.—What should be done if a main wheel breaks off its axle?

A.—Would disconnect on broken side and remove all the side-rods and the broken wheel. The eccentrics would serve to prevent the other wheel from leaving the rail. Even though a blind tire, would use a jack to raise the axles on the broken side. Remove the oil cellar and fit a hardwood block between the driving axle and the pedestal jaw or binder. Old rod-keys or any kind of iron could be used to block between the spring saddle and the top of the frame to keep part of the weight off the axle at that point. Then the jack should be removed. Would next slightly raise the engine on the broken side and block between the top of the driving box or the boxes nearest to the main wheel on the broken side, using hardwood or iron. If an eight-wheeled engine would also block between the engine truck equalizers and the truck frame on both sides, because additional weight would be imposed upon the truck. If a consoli-

dated engine, would block on top of the two boxes nearest the main box only. The engine should then be let down and run slowly.

Q. 5.—If a main wheel is cracked, what should be done?

A.—If possible, would run engine slowly to the first side-track, provided the wheel were not too badly broken, but would watch it closely. Then would disconnect broken side and remove all the side-rods so as to take the strain off the crank pin on the broken wheel, and it might then be possible to proceed. But, if the break were bad enough to render it unsafe to proceed "light," would block the wheel up to clear the rail the same as for a broken tire. Then would run very slowly and carefully.

Q. 6.—If a main driving axle breaks, what should be done?

A.—If an eight-wheel engine with the axle broken off outside of the driving box, would re-

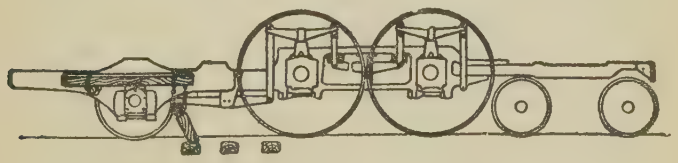


Fig. 33.
Method of Raising Cross-Equalizer.

move the spring over the broken axle and jack up the broken axle to free the driving box cellar. Would next remove the cellar and fit a solid block of wood between the axle and the binder brace and nail a strip across each side to prevent it from

falling out. All the side-rods would have to be taken down and the engine run slowly, using only one side.

Q. 7.—If an axle or a back tire breaks on a consolidation engine, what should be done?

A.—If the back driving axle broke and if no other damage were done, would remove both sections of the side-rods, jack up the broken end of the journal level and make it secure by blocking between the bottom of the box and the pedestal brace. If the firebox extended over the frame and the springs were between the pedestal jaws and under the top, would pry up the back end of the spring as high as possible and block there. If necessary, would disconnect the front end of the back equalizer. If the springs and equalizers were above the frame, would block between the top of the frame and the spring saddle. The object, in either case, being to relieve the box of the weight it carries. If the second and third drivers had blind tires, would chain around the tail-piece of the engine frame on the disabled side and across to the opposite side to the front corner of the tender frame, using wedges to make it hold as tightly as possible. This would crowd the engine over against the flanged driver. Would cut out the driver brake and then run engine carefully, especially around curves and through frogs and switches.

For a broken tire, would follow the same procedure, with the exception of taking down the back sections of the side-rods, which in this case could be left up, provided they were not damaged badly

enough to warrant their removal.

Q. 8.—If a tender truck axle or wheel breaks, what should be done?

A.—If the front wheel or the axle of the leading tender truck were broken and no jacks available, would take up all the slack by twisting the check or safety chains. Then would put a block at an angle between the tie and the tender frame and move the engine a few inches ahead to raise the tender frame and carry the truck up at the disabled end. After blocking the truck, would let down the tender frame by backing off the block; tighten the safety chains and, if necessary, raise the tender frame again in the same manner. Would put a rail across the tender frame or on the water-bottom over the shoveling plate, and chain the disabled end of the truck to the ends of it. Would chain the broken axle to prevent it from falling down or getting in the way. If any other wheel or axle were broken in the tender, would follow the same general procedure. A piece of rail or a long, stout piece of wood could be put across top of tender over the coping, but to prevent it from bearing upon the coping it should be blocked on top of the tank plates. The defective end of the truck on each side could then be chained to the overhanging end of the rail or wood (as may be) the good boxes blocked over and the frame blocked under to relieve the strain on the chain.

CHAPTER XII.

LUBRICATION.*

Q. 1.—What should be done when a box gets hot?

A.—When a box gets hot where grease is not used, would discontinue the use of car or engine oil and use valve oil. If possible, would cool the box before using any oil. Because to pour engine oil on a hot box without cooling it down to normal temperature would be adding fuel to the flames.

Q. 2. –When a box or bearing heats, what is the first thing which should be noted?

A.—Would first see if it had been getting all the oil intended for it and whether any unusual condition had caused it to heat. These troubles usually occur when minutes are precious so there would be no time to waste. If the oil had not been reaching the bearings in sufficient quantities would remedy it as quickly as possible and give a more liberal supply until conditions became again normal.

Q. 3.—If an engine truck journal, tank truck journal or driving journal became too hot, what should be done to remedy it?

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* For further particulars in regard to Lubrication the reader is referred to another volume of "The Science of Railways" series relating to Locomotive Appliances.

A.—If engine were equipped with water pipes for the purpose would turn on the water and have the box repacked at terminal. If not so equipped and the box were not too hot, would give repeated liberal supplies of valve oil, which usually answers until terminal can be reached. If it became necessary to pack the box, would cool it down thoroughly before doing so. If a driving cellar were behind the eccentrics, would run in at a slower rate of speed, if necessary, because less time would be lost than would be lost in packing it, were it possible to do so on the road. By cooling it down occasionally and giving it a free supply of valve oil one can usually go along in good shape. A hot eccentric may be run at a high rate of speed, if oiled liberally every few miles with valve oil, and unless something out of the ordinary were the matter it would eventually cool down. It would be best to leave the eccentric straps open unless they had been recently closed and were heating on account of being too tight. If they had been running good, a stopped-up oil-hole or some foreign substance between the eccentric and straps would most likely be found to be the cause of the trouble. Sometimes a brass is allowed to remain in a tank-truck or engine-truck oil box until it becomes too thin, and so causes the box to heat. Or, it may split and cut the journal and so require renewing on the road. It would be better to have these changes made before trouble occurs. Practical experience will usually enable an engineer to tell when a brass has worn to about the limit of thinness. A driving brass worn too thin gives

trouble until it is replaced with a heavy one. The speed of train also has a bearing on these matters.

Q. 4.—In replacing a box, what care should be exercised?

A.—Would see that packing was thoroughly saturated with oil, and pushed to back of the box to lubricate the rear of the journal. Also that the packing was not put into the box so tightly as to force out the oil and so cause the packing to become hard and dry. Packing should fill the box loosely, so care should be taken to see that it reaches well up to the journal. Attention to these things before going out saves much annoyance and delay on the road. It is not the amount of oil used but the fact that what is used is applied at the proper time and in the proper place and manner that counts.

Q. 5.—To insure the oil reaching the bearings in very cold weather, what should be done?

A.—Oil holes opened frequently and the average engine oil thinned with kerosene, otherwise it would not lubricate until a bearing became hot and warmed it. If not thinned with kerosene, the oil in a hand oiler taken from the boiler-head becomes too thick to use, in very cold weather, before one can get around his engine.

Q. 6.—How is grease, or, as it is sometimes termed, hard oil, applied to crank pins?

A.—A large hollow cup is attached to the top side of the rod straps. A small hole leads from the bottom of the cup down through the strap to the pin. The inner side of this cup is threaded to fit a plug that is screwed down on the grease

within the cup, forcing it down on the pin until the supply within the cup is exhausted. A turn or a little more than a turn is sufficient to run a pin an ordinary trip under normal conditions.

If grease is forced down too hard on a pin it tends to increase friction and heat, and the grease forced out around the collar of the pin and the hub of the wheel is largely wasted, and the cost of lubrication is thus increased. Experience enables engineers to know when the grease under the plug feels firm enough to indicate that sufficient pressure has been applied to it and that it is time to quit forcing the plug down.

Pins will run warmer with grease than with oil as a lubricant, partly owing to the grease causing a little more friction and partly owing to the fact that it does not commence to lubricate until slightly warmed. There is practically no danger of throwing the babbitt or cutting a pin if grease is kept on the bearing, but, of course, more will be used.

A hard rain storm washes the grease away from around the collars so the plugs then need to be screwed down more often than ordinarily.

Water used on crank pins equipped with a grease-cup washes the lubricant away. Therefore neither water nor oil should be used, because the grease is capable of meeting all requirements if properly supplied.

Q. 7.—How is grease applied to driving journals?

A.—A plate is used in the driving cellar called a follower plate. Between this plate and the bot-

tom of the cellar a spring is located that crowds the follower plate upwards. The grease is placed on top of the follower plate in strips the length of the journal bearing, and as the grease is worn away by the revolving journal the spring pushes it up until the supply is exhausted. The strips of grease do not come in direct contact with the journal, but the grease is forced through a perforated plate at the top of the cellar to the journal.

Q. 8.—How may it be known when the supply of grease in a cellar is exhausted?

A.—By two indicators fastened to the follower plates and extending down through the bottom of the cellar. They are located one near each end of the cellar. When the rings at the lower end of the indicators are up to the bottom of the cellar it is time to repack it.

Q. 9.—Should an engineer note the condition of grease cellars before going out on a trip?

A.—Yes: while it ought not to be necessary for him to do so, yet it may save him a great deal of bother later on.

A cellar runs a good many thousand miles with one filling, so the indicators do not need to show much in the cellar in order for it to contain enough to make one trip.

Q. 10.—How should a driving cellar be packed, if necessary, with grease on the road?

A.—Would remove plate on front of cellar. Pull indicators down and fasten them. This would bring follower plate down so that strips of grease equal to the length of the journal bearing could be laid on it.

Would put side strips in first and fill the center next. Would replace end plate and release indicators. Grease for collars is harder than that used in rod cups. A supply for emergencies is a good thing to have on one's engine.

Q. 11.—Are any changes necessary in the driving box when grease is used in the driving cellars instead of waste and oil?

A.—Yes, several. There is no oil hole in the top of the box or bearing, nor grooves in the latter, but, instead, slots are cut in the sides of the bearing.

CHAPTER XIII.

LUBRICATORS.*

Q. 1.—If a cylinder lubricator would not work, what should be done?

A.—The lubricator should be disconnected and the cylinders oiled through the feed pipes the same as was formerly done with the old-fashioned cylinder lubricators. Exactly how to do it depends somewhat upon the type of lubricator. It is usually possible to disconnect it so the work may be done as follows:

For example—With a Nathan lubricator, as shown in Fig. 18, which may have stopped feeding oil because of the glass breaking, or for any other reason, the valves A and B should be closed. This would cut off the flow of oil through the glass of passage affected, but would not in any way interfere with the rest of the lubricator.

The special tallow cups C, provided on these lubricators, may be opened and used in the same way as the old-fashioned cab oilers when the engine is on a down grade, or at any other time when drifting with the throttle closed. They may be used, also, at any time to supplement the sup-

* For further particulars in regard to Lubricators the reader is referred to another volume of "The Science of Railways" series relating to Locomotive Appliances.

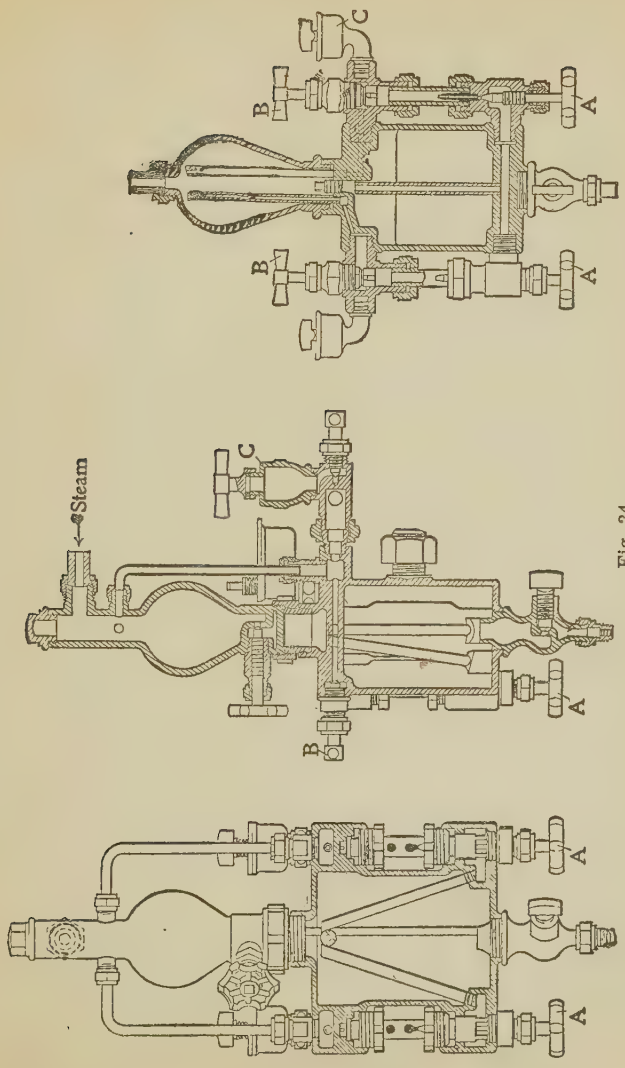


Fig. 34.
Nathan Cylinder Lubricator.

ply of oil to the cylinder in any quantity, as in the case of common non-automatic lubricators. This method could be employed with possibly some changes in detail of operation and arrangements with all types of sight-feed automatic lubricators.

Q. 2.—What would cause irregular action of an automatic sight-feed cylinder lubricator?

A.—If the fitting of the choke plugs were too loose, or the feed holes too large, the result would be an intermittent feed. This hole should not be more than 1-32 inch in diameter. An obstruction in the equalizing tubes would also cause an irregular action. These tubes should be kept free and clean and the choke plugs tight.

Q. 3.—What should first be done when a lubricator does not work?

A.—The bottom cocks opened and a full head of steam turned on, in order to blow it out. Should this fail to put it in operation the sight feed glasses should be taken out and the feeders examined at the bottom, where they should be clean and clear. Should this fail it should be disconnected, as already explained.

Q. 4.—If a Nathan lubricator fails to feed, although the feed glasses fill with water while not working, and all the water leaves the glass as soon as an attempt is made to use the feed, what is most likely to be the trouble?

A.—The trouble could be caused by not having had full steam pressure on the lubricator when the engine was moved out of the roundhouse. The water valve was probably opened, but not the steam valve. Hence, there was a direct opening

from the lubricator to the steam chest by reason of the water valve drawing the condensed water from the condenser and then siphoning the oil through the water tube out of the oil chamber. This would cause the water from the sight-feed glasses, together with any oil on top thereof, to be drawn into the oil chamber. This would last until the oil chamber became solidly full, then the feed glasses would fill up with water again, and if, in the meantime, the condenser regained condensed water, the cup would feed oil again. The remedy would be in opening the steam valve full before the engine was moved.

Q. 5.—If the water gauge glass breaks, what should be done?

A.—If the fittings were not supplied with automatic, self-closing valves this, although only a minor accident, might cause serious injury to the enginemen, especially the fireman, by pieces of flying glass. The cocks at top and bottom of fitting should be closed, thus shutting off the escaping steam. The gauge cocks should be used to learn the water level for the rest of the trip.

Q. 6.—Where should the trouble be looked for when a lubricator feeds irregularly?

A.—If a Detroit lubricator feeds irregularly, the trouble should be looked for at the automatic steam chest valves (see Fig. 35) or in such chokes as are located at the lubricator end of tallow pipes. When the opening through any of these chokes is enlarged above the standard, the feed will "race" or be more rapid.

The function of these automatic steam chest

plugs and valves is twofold: First, that by their use and location the lubricators feed against a constant boiler pressure and not against a fluctu-

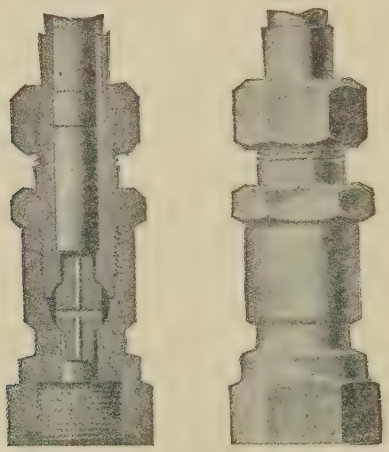


Fig. 35.
Detroit Lubricator Automatic Steam Chest Plug and Valve.

ating pressure as was the practice in the earlier type of lubricators; second, the valves or chokes restrict the flow of steam to the steam chest to that volume that will balance the feeds to a uniform rate, regardless of the position of throttle or lever.

CHAPTER XIV.

INJECTORS.*

Q. 1.—Why will a lifting injector not restart when it breaks?

A.—Because the injector having a closed overflow the steam flows back through the tank hose into the tank when the injector breaks, thus the water in the tank is kept from reaching the injector.

Q. 2.—Why will the restarting injector start working automatically when it breaks?

A.—Because passages are provided for the escape of the steam to the atmosphere when the injector breaks, and as the water continues to reach the injector, it works automatically.

Q. 3.—If an injector had been working satisfactorily and suddenly stopped working, where first should the trouble be looked for?

A.—In the water supply. The tank valve might have become disconnected. The strainer might be stopped up or fine coal or cinders might have gathered about the tank valve.

Q. 4.—How could the obstruction be removed without stopping the engine and taking the hose down?

* For further particulars in regard to Injectors the reader is referred to another volume of "The Science of Railways" series relating to Locomotive Appliances.

A.—By closing the overflow valve and blowing a heavy jet of steam back through the tank hose from the injector steam throttle; if this would not suffice it would be necessary to take the hose down at the first opportunity. Should air suck into the feed pipe at any point the injector would break, so would look out for this trouble also.

Q. 5.—What would cause an injector to fail to prime?

A.—Low water in the tank, leaky boiler check-valve, or other leak of steam to injector, which would destroy the vacuum, or through an overflow pipe being stopped up.

Q. 6.—In case an injector had not been used for some time, what might occur?

A.—The boiler check valve might have become corroded and stuck fast to its seat so injector could not work, or the tubes might have become corroded and partly stopped up.

Q. 7.—If a boiler check valve would only partly lift when injector was started, what would be the result?

A.—Water would be thrown out on the ground through the overflow pipe.

Q. 8.—Under either of these conditions could anything be done to remedy it?

A.—Would open cock to frost pipe and tap boiler check-valve cage and try to work the injector; this sometimes loosens the valve from its seat and permits the injector to work properly.

Q. 9.—What effect has loose tubes on the working of an injector?

A.—They cause the injector to break.

Q. 10.—If the steam furnished by the injector steam throttle is not all condensed, what would be the result?

A.—The injector would not work, or would only partly take up the water. To remedy it would either reduce the supply of steam or increase the supply of water.

Q. 11.—Would variation of steam pressure on the boiler have any effect on the working of an injector?

A.—Yes; were the steam pressure to fall considerably, the supply of water would have to be decreased or the injector would not take it all up, or the boiler would be oversupplied with water.

Q. 12.—What effect does bad water have upon injectors?

A.—It corrodes or limes them up. They soon get in such a bad condition that they will not work. A bath in muriatic acid becomes necessary, in order to restore them to good working condition.

Q. 13.—Which injector corrodes most quickly, a lifting or non-lifting injector?

A.—A lifting injector, on account of steam being continually in the body of the injector. In some localities where the water is very bad and injectors corrode quickly, only the non-lifting injectors are used, in order to avoid so often changing and cleaning injectors.

Q. 14.—When a water glass is broken, how may a new glass be cut to replace it?

A.—By making a scratch around the inside of the glass tube with a piece of hardened steel with

a bent point, the tube can then easily and accurately be broken where marked.

Q. 15.—What precautions ought to be taken when replacing a broken water glass?

A.—If, when replacing it, the boiler is hot the packing at the ends of the glass should be screwed up very loosely to provide against unequal expansion between the glass and the frame, which would, of course, put too much pressure on the glass and break it. When in position it should be allowed to stand long enough to become as warm as when in contact with the heated parts of the frame. Then the upper valve should be started enough to allow a little leakage of steam into the glass. Then a considerable amount of condensation should be allowed to collect at the bottom before the lower valve is started in the same way. Then when the water level indicates approximately the same level as the boiler, the valves should be gradually opened until in their normal working position.

Then the packing glands should be screwed carefully and gradually until all the leaking stops. However, it should be remembered it is better to have a leak than to screw in the packing too rapidly, because the glass should be perfectly free to expand lengthwise and diametrically, in order to adjust itself to normal working condition and be free from strain.

Q. 16.—What was the trouble with these injectors? Following is an account of their action:

"Everything went right until it became necessary to use the second injector to keep water

in the boiler; then trouble began; neither would work satisfactorily and both threw water on the ground, although one injector at a time would work on either side. The main steam valve to the turret, or combination valve, was wide open and the other boiler attachments, such as blower, lubricator and air-pump, worked all right."

A.—In this case it is evident the trouble was not in the injectors, because they worked all right when but one at a time was used. They did not get a sufficient quantity of steam to force the

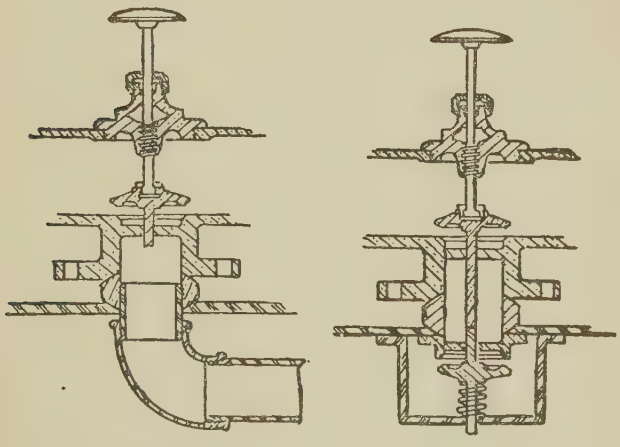


Fig. 36.
Injector Valves.

water into the boiler. This could have been caused by some obstruction in the steam pipe leading from the dome to the combination valve, or turret. A rivet, stud or nut may have dropped into the steam pipe, obstructing the flow of steam from the

boiler to the injector throttles; or, the area of the opening which leads from the boiler to the main valve may have been insufficient to equal the combined area of the valves for the other boiler attachments. Sometimes this trouble occurs through the use of a combination valve designed for safety in case of accident. The two illustrations show valves of the same exterior appearance. The one with the single valve, Fig. A, is fast to the stem. It can be opened wide by raising it ¼ inch from its seat for every inch of diameter, and if then given a turn or two will do no harm. But the other, Fig. B, with the double valve, should only be opened to about the middle position, as shown in the cut. Should this valve be opened the same as the other it is obvious the spring under the lower valve would force it to its seat and reduce the flow of steam, if it did not shut it off entirely, so both injectors would not work at the same time, because of insufficient steam. The effect of the restriction would not be as apparent on the action of the blower, air-pump, and lubricator; although, if they get a liberal supply of steam to the turret, they will work much better.

CHAPTER XV.

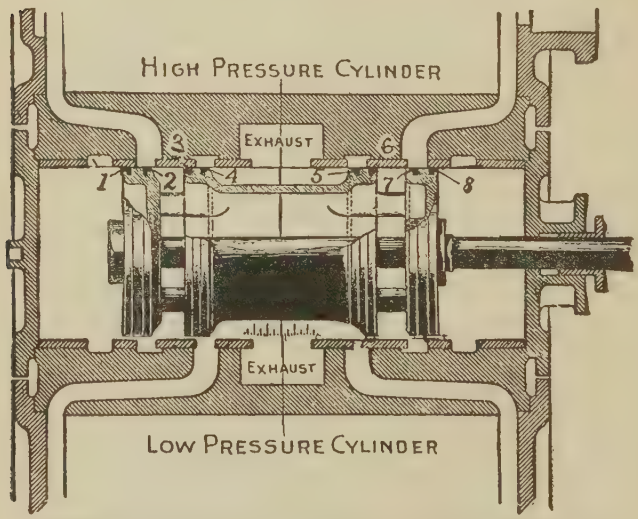
COMPOUNDS.

Q. 1.—How should a test be made of valve blows in a Vauclain four-cylinder?

A.—It is quite difficult to distinguish the difference in blows because several different defects produce the same effect on the valve motion, or the sound of the exhaust in a Vauclain compound. Care should be taken not to mistake two light exhausts on one side for two heavy exhausts on the other. One loud exhaust on the Vauclain compound could be caused by rings either Nos. 1, 2, 3, 6, 7 or 8 being broken. Rings Nos. 1 and 8 broken would give more port opening at the end of the high pressure cylinder on which the ring was broken. This would go to the opposite end of the low-pressure cylinder and produce a heavy exhaust. If rings Nos. 3 or 6 were broken, the volume of steam admitted to the low-pressure cylinder would be increased with the same effect. If rings Nos. 2 or 7 were broken, it would give one heavy exhaust on that side of the engine, because the steam would blow past the ring from the live steam-way directly into the hollow of the valve, when the steam port at the opposite end of the valve was open. If a heavy exhaust should come from the front end of the

right side it could be caused by rings Nos. 8 or 2 being broken, which would increase the pressure in the low-pressure cylinder, producing a heavy exhaust. The illustration and method of making tests is as follows:

The engine should be placed on the bottom quarter on the side to be tested; the drivers



Testing for Valve Blows in a Vauclain Four-Cylinder Compound.
Fig. 37.

blocked or the brakes set, and then both indicator plugs on the high-pressure cylinder should be removed. If the engine were not equipped with plugs, the pops of the water relief valves on the cylinder heads should be removed, the engine given steam and care taken to see that the throttle was opened sufficiently to set the packing rings

out against the bushing. If the ports could be covered, it would show rings 1 and 8 to be in good order. In making a test for a high-pressure packing blow, the reverse lever should be put in forward motion, which would open the front port to the high-pressure cylinder; the starting valve should be closed and the indicator plug or pop should be at the back end of the high-pressure cylinder. When steam blows out of the indicator plug, the high pressure packing may be blowing, or ring No. 7 may be broken. To determine which, the indicator plug should be replaced in the back end, the front end removed and the reverse lever put in the back motion, and the same test made. If the high-pressure packing, it would then show; if ring No. 7 it would not show. To make a test for the low-pressure packing, the reverse lever should be put in forward motion with all the indicator plugs in except the one in the back end of the low-pressure cylinder. The starting valve should then be opened, which would admit steam to the back end of the high-pressure cylinder, the hollow of the valve and the front end of the low-pressure cylinder. Then if the low-pressure packing were blowing it could be noted at the back of the indicator plug. In this position, if rings Nos. 3 and 4 or 5 and 6 were broken, steam would blow through the stack. The blow would, in either case, be light, because to produce it the steam would have to pass through the starting valve.

Q. 2.—What should be done when the stem of intercepting valve breaks on a Schenectady two-cylinder compound?

A.—The engine should be run simple, after the valve has been blocked so as to allow it. This could easily be done by clamping the stem or rod, but, if not, the head should be removed and a block inserted to hold the valve in place and the head replaced.

Q. 3.—What should be done if the by-pass valve breaks on low-pressure side of Schenectady compound?

A.—To locate a defective by-pass valve on the low-pressure side of a Schenectady two-cylinder compound, the engine should be placed on upper quarter on the low-pressure side and the lever reversed in forward motion. The separate exhaust valve should be closed by placing the three-way cock in the compound position to admit steam to the cylinder. Then if a blow came from the exhaust the defect would be found in the forward by-pass valve. Should a blow occur with the lever in the back motion (engine in same position), the defect would be found in the back by-pass valve.

Q. 4.—What should be done if the by-pass valve breaks on high-pressure side of Schenectady compound?

A.—The same as for the low-pressure side, except that in this case, the separate exhaust valve would be opened by placing the three-way cock in simple position. A blow from a broken by-pass valve may easily be distinguished from other blows. It is very strong, occurring only during one stroke of the piston. For example—If the blow occurs during the forward stroke, the defect

would be found in the forward valve. To remedy it, the by-pass valve casing should be removed from the side of the cylinder and both openings covered with a thin copper or sheet-iron gasket; then the casing should be replaced.

Q. 5.—What should be done when a cylinder head is broken on a Schenectady compound?

A.—If the high-pressure side were disabled it should be disconnected and blocked, the ports covered and the separate exhaust valve opened the same as when running simple. If the low-pressure side were disabled, would block, cover the ports and open the separate exhaust valve. In the event the engine was without air for the operation of the separate exhaust valve, would remove head from cylinder and insert a block, preferably of wood, about three inches thick, and replace the head over the block.

Q. 6.—What should be done if a steam chest breaks on a two-cylinder Schenectady compound?

A.—If a low-pressure steam chest were broken the high-pressure side should be used as a simple engine, which could be done by taking out the intercepting valve and blocking the reducing valve in the closed position, so that when the intercepting valve has been replaced, steam could not get to the low-pressure side with the intercepting valve in simple position.

Q. 7.—What should be done if a forward motion eccentric on left side were broken on Schenectady compound?

A.—The ports covered, valve rod disconnected, the remnant of the broken eccentric removed, and

also the back motion and the main rod taken down and live steam used in the low-pressure cylinder to run the engine.

Q. 8.—What should be done when valve rings break on a Schenectady compound?

A.—If the rings were not caught in the ports, would use less throttle than when ordinarily working the engine compound. The steam which would leak by the broken rings would pass into the receiver, and could do effective work in the low-pressure cylinder.

Q. 9.—How should test be made for a blow in low-pressure cylinder of Schenectady cross compound?

A.—The handle of the operating valve should be moved to simple position, and the test made in the usual manner the same as for a simple engine.

Q. 10.—What should be done when a low-pressure head is gone from a Schenectady cross compound?

A.—The valve stem on the disabled side should be disconnected, the valve blocked in the center of the seat, the separate exhaust valve opened and the engine run on one side.

Q. 11.—What should be done when a high-pressure cylinder head is blown off a Schenectady cross compound.

A.—The valve stem on the high-pressure side should be disconnected, the ports covered, the engine cut into simple position and run on one side. The separate exhaust valve should be kept open, so that in case the high-pressure valve were

to leak or shift, steam would not bank up in the receiver and temporarily interfere with the working of the engine.

Q. 12.—What should be done when a transmission bar is broken on a Schenectady cross compound?

A.—If the transmission bar were broken on the right or low-pressure side, the broken parts should be removed if they would be likely to interfere and cause further damage, and the valve blocked central. The excess pressure valves in the low-pressure cylinder heads should then be removed, the separate exhaust valve opened, and engine run on one side. If the left or high-pressure side transmission bar were broken, the same procedure should be followed for the right side, except that it would be necessary in that case to cut the engine into simple position. If there were no excess pressure valves in the cylinder heads, it also would be necessary, in order to oil the piston, either to loosen up the front cylinder head, or block the valve so that the back port would be opened enough to admit a little steam. This would allow the lubricator on that side to be worked to keep the cylinder oiled. Taking down the main rod would be inadvisable, as the engine might get stuck on the center, and, in that event, it would be needed to help get it off.

Q. 13.—What should be done when a high-pressure piston is broken off rod on Schenectady cross compound?

A.—If, in breaking off, the front cylinder head were not knocked out, it should first be removed

and the piston head taken out (to prevent its being lost). Then the valve stem should be disconnected and the ports covered on that side, the engine cut into simple position and run on one side.

If the front cylinder head were not knocked off, it should be taken off, and the piston head removed (to prevent losing); then the cylinder head should be replaced, the valve stem disconnected, and the ports covered on that side, the engine cut into simple position and run on one side.

Q. 14.—What should be done with separate exhaust valve stuck on Schenectady cross compound?

A.—The separate exhaust valve sticking shut is generally due to gum or dirt, caused through using engine oil. This can best be corrected by a liberal application of headlight oil, followed by valve oil. If quite certain that the pipe leading to the separate exhaust valve (emergency pipe) is open, a sharp blow on the head of the chamber with a block of wood may jar the valve loose. The valve sticks shut either because it is gummed up or the emergency pipe leading to it is stopped up.

Q. 15.—What should be done when the low-pressure side is demolished on a Richmond compound?

A.—Assuming the cylinder to be broken off entirely, if the cylinder saddle and intercepting valve were not damaged, all the broken parts on the disabled side should be taken down, a blind gasket slipped over the steam port leading from the small steam pipe to the reducing valve chamber, the intercepting valve blocked shut, and the engine run with high-pressure side. On account of the

restricted opening through the separate exhaust valve, the best speed possible with a train would be about eight to ten miles per hour.

Q. 16.—What should be done when a side-rod is broken on a four-wheel, connected (balanced) Baldwin compound?

A.—If the side-rod breaks on an engine of this type, where the high-pressure cylinders are connected to the front axle and the low-pressure cylinders are connected to the second driving axle, the eccentrics being on the second axle, the high-pressure piston should be removed and the locomotive run with the low-pressure cylinders. Under these conditions the engine could be run as a single expansion engine; the high-pressure cylinders merely serving as a steam chest for the low-pressure cylinders.

For further details regarding the operation of Compounds, see the volume of "The Science of Railways" series, "Engineers and Firemen's Handbook."

CHAPTER XVI.

AUTOMATIC BELL-RINGERS.*

The automatic bell-ringer is usually operated by air; it consists of a crank attached to the bell yoke; from this crank a small rod passes down inside a pipe or hollow shaft which is connected with the piston rod. The air cylinder is attached to the bottom of the bell stand and contains the valve that controls the admission, cut-off and exhaust of the air, and the piston and piston rod.

The air is admitted to the bell-ringer by a globe valve located in the cab, and is conveyed to the air cylinder by a small pipe connected to the main reservoir pipe below the engineer's brake valve.

The valve in the air cylinder works over air inlet port and exhaust port. The admitted air strikes the valve in the cylinder and forces the piston up until the exhaust port is opened and the admission is closed by the movement of the valve, then the air escapes and the weight of the bell pushes the piston down, and the valve back to its former position; when, the admission port being opened, the piston is again forced up by the

* For further particulars in regard to various styles of Automatic Bell Ringers the reader is referred to another volume of "The Science of Railways" series relating to Locomotive Appliances.

action of the compressed air. The travel of the crank rod is adjusted to regulate the motion of the bell by an adjusting screw.

Too much crank rod travel or too much air admission causes the bell to turn over and over instead of moving back and forth as intended. Sometimes more air must be admitted to start a bell than is necessary to move it properly; but after it is once started, if the supply is reduced, the bell will work properly.

Valve oil should be used sparingly in the air cylinder of a bell-ringer. The yoke bearings on the bell stand should be kept well oiled to reduce friction and wear.

Q.—Should a bell-ringer refuse to work, what should be done?

A.—Failure of this part of the engine mechanism is usually due to neglect. Dirt is usually the cause. Notwithstanding whether compressed air or steam be employed for its operation, oil to lubricate the cylinder must be used. As a rule, the trouble is not that an insufficient quantity is supplied, but too much, and generally in larger quantities than the cylinder can take care of; as a result, the exhaust pipe soon becomes filled with cooked oil, the pressure cannot escape as the bell pushes the piston down, and the apparatus becomes choked. When a bell-ringer fails to work it should be taken apart to see that it is clean.

Bell-ringers are usually operated by a single acting piston, the valve, in one direction at least, being moved by the weight of the bell. The mechanism ordinarily is very simple. Yet failure to

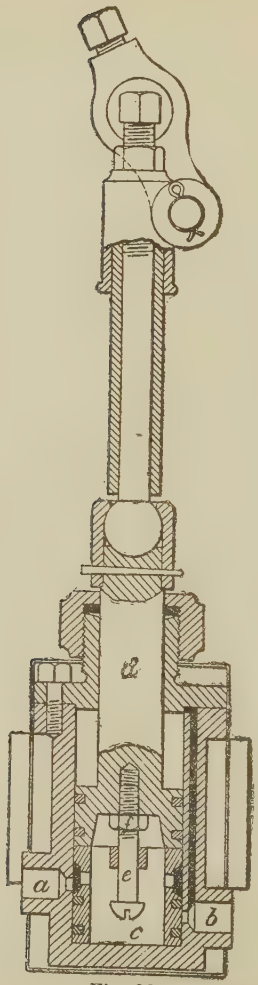


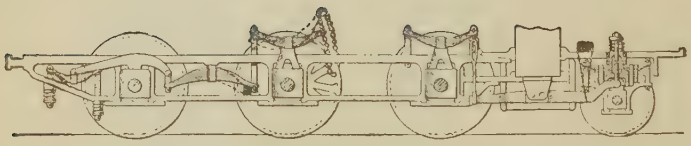
Fig. 38.
Gollman Automatic Bell Ringer.

operate may easily occur. For example, in the Gollmar ringer, shown in Fig. 38. The air or steam (as the case may be) is admitted through port *a* to the interior of the hollow cylindrical valve *c*. As piston *d* is raised by this pressure, the end of the stem *e* strikes against the lug of the valve *c*, through which it passes. So that the exhaust may escape, valve *c* should be raised high enough for its lower edge to be above the exhaust opening *b*.

The stem *e*, after being adjusted, is held in its proper position by the check nut *f*. Should this nut work loose and the stud *e* unscrew, valve *c* will not be raised high enough to allow the exhaust to escape, resulting in the ringer being stopped.

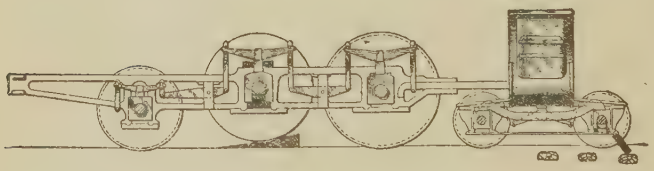
Stoppage may also result from a leakage of the piston packing ring, but comes on very slowly, and manifests itself by a gradual weakening of its action so there should be no difficulty in locating the trouble.

The mechanism being so simple, the cylinder head should be taken off and all parts removed and examination made when it refuses to work. By measuring the height of the exhaust port *b* above the bottom of the cylinder and knowing the stroke of the piston, it is an easy matter to subtract the former from the latter and ascertain whether the stem *e* is adjusted to give the proper lift or not.

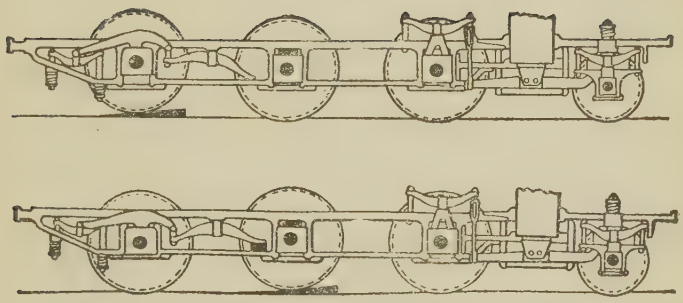


Method of Pulling a Driving Spring into Position with a Chain.

Also indicating how front end of long equalizer can be chained up when Bissel pin is broken.



Showing How to Raise Wheel to Block for Broken Tire, or to Raise Engine Truck with Fulcrum Block to Replace Brass in case of a Hot Engine Truck Bearing.



Method of Blocking for Broken Spring, Spring Hanger, or Equalizer.

First raise frame by running wheel up on wedge, and block as indicated by upper figure. Next raise second driver on wedge as indicated by lower figure, which will release tension so that block can be placed under spring as indicated.

BOOK II.

THE MOTIVE POWER DEPARTMENT

INTRODUCTION.

The motive power of a railroad is like cash in hand or good credit in the case of an individual. It makes things go; and if wisely handled represents a great and potential force—Prosperity, in fact. The care and wisdom exercised, therefore, in Supervising and administering the locomotive department tends to the prosperity of railroads, or the reverse. Everything, then, that helps toward good government, adds knowledge and incentive in regard to the affairs of this great and little known department, is not only of value to the department but to owners and managers generally. Hence the writing of books like this and others relating to railway operations. To the widely experienced and responsible officials in charge of the power department, what is written, descriptive and otherwise, of their branch of the service may seem superficial; of little or no value—primary in fact. And this is true so far as it personally concerns such officials. However, technical books are not written for those already wise, but for those who seek wisdom; who wish to supplement their limited knowledge and experience with that of others.

CHAPTER I.

SUPERVISORY METHODS OF THE MOTIVE POWER DEPARTMENT AND THEIR EXTENT AND USEFULNESS.

In connection with the supervisory work of locomotives, it needs no argument with practical railway men to prove that, in order to secure the greatest possible economy and effectiveness of both engines and machinery, they should be maintained at the maximum efficiency. Not only is cost of repairs greatly increased with every hour of neglect, but effective service is correspondingly impaired. The usurious price that a railway company pays for shortage of equipment or lack of means to remove an engine from service and make repairs as needed, is out of all proportion to the saving effected in the number of locomotives or the momentary lightening of the expense account. It is with locomotives and machinery as it is with a leaky roof; not only is the immediate defect heightened, but it involves other and multiplied losses, so that the ultimate cost of repairs spreads and increases with every hour of neglect. "A stitch in time saves nine" is not a mere figure of speech but the dictate of a wise and thrifty housewife; and it is a maxim that applies with even greater force to the complex and costly machinery of a locomotive, the wear and tear of which is constant and destructive under the most favorable circumstances.

Every one immediately responsible for the use and care of the locomotives and machinery of a railroad fully appreciates this. But their wisdom and effectiveness is rendered nugatory if it is not equally well understood—and acted upon—by their superiors who are immediately responsible for operations as a whole.

A feature of locomotive supervision that the onlooker does not much regard if, indeed, he thinks of it at all, is the practical knowledge and acumen required to apportion locomotives to the various parts of a road with good judgment, according to the fitness of the machine to do the work, the urgency of the work, and its comparative value from the earnings point of view to the carrier. In the case of a widely extended railway—and all of our railways are widely extended—the distribution of engines to meet needed requirements when business is pressing, must at once tax and rack those in charge of motive power almost to the point of desperation. For it goes without saying that no railroad can possibly provide itself with sufficient engines to do, with ease, the maximum amount of service that may be required for a particular day, or week, or month in the year. The number necessary to meet ordinary conditions, with a margin for emergencies, is the most that any company can afford. When, therefore, a rush occurs as it will frequently, and often unexpectedly, the niceties, perplexities, and harassments of apportioning the engines judiciously to meet such emergencies, is too apparent to require comment. This is one feature of locomotive supervision and perhaps as important, if not more important, than any other single thing connected with the service. How to get the most out of the power, make it most productive of revenue and public utility, with the least incidental expense, wear and tear, and disarrangement of service, is the problem that ever confronts those in charge. For in order to utilize locomotives to the best advantage in emergencies (and at other times as well), it is not only necessary to know what particular engines are in service or available for service, but what each engine can do; what kind of service it is best adapted to. For in the economy of the department, machines are classed all the way from the light serviceable en-

gines to those capable of hauling a heavy train at the highest rate of speed. There is as much difference, it may be truly said, between locomotives as there is between men or women. Some will work cheerfully and to their fullest capacity in all kinds of weather and under all circumstances; while others must be coddled and petted and fussed over. One will be capable of hauling a great load at a high rate of speed; while another will haul a great load but only at the minimum rate. Some will be quick to move, others slow. The condition of the engine has also to be considered. And so it goes; each having peculiarities that require those in charge to be familiar with in order to use them to the best advantage.

In practical working it has been found to conserve both economy and effectiveness to keep expert engineers traveling on a line to scrutinize the workings of engines and give directions to engineers and firemen as circumstances require, or the improvements and changes in service, from time to time, suggest. Such supervisory work is found especially necessary and valuable in connection with the use of fuel. If the firing of an engine is carelessly or ignorantly performed, great waste of fuel and power occur in consequence. Both economy, the good of the machine and the load hauled, depend so much upon scientific firing that this feature of the service claims and receives the constant attention of those responsible for effective working of the motive power department.

Another supervisory feature of the service is the critical examinations firemen must pass, both before entering the service and at the end of the first, second and third years of their work; and, indeed, after they have been commissioned as engineers, up to the time they are admitted to the passenger service. Such examinations were unknown in early days as were many other features now thought indispensable. In-

deed, many roads now seek to correct the deficiency in former practice, as regards examination of firemen, by requiring engineers, who did not pass such an examination, to do so now. This on the theory that such examinations are not only necessary for the good of the company and the safety of the public, but for the well-being of the engineer himself. However, practical experience counts for much (is better than perfection in theory), and so the examinations in respect to old engineers are not, it may be said, as rigid as in the case of firemen progressing toward a higher position.

Of the intrinsic value of these examinations there can be no question and the writer has had many commendatory letters from engineers and firemen in regard to the value to them of certain parts of the "Science of Railways" that relate to such matters, as well as those of a more general nature in regard to the department of motive power and machinery.

It is perhaps true in regard to the supervision and needs of locomotives, that if all those that a railroad operates passed daily under the scrutiny of the official in charge of the department, his personal supervision over them, his knowledge of their needs in the way of repairs and betterments, would perhaps suffice—provided he was also able to look after the practical things connected therewith, such as the scrutiny of the parts affected, details of labor and machinery and tools. But this is impossible. He can only be at one place at a time while his engines are scattered over hundreds or thousands of miles of roads, some actively employed, others filling the round house and repair shops. Yet he must have definite knowledge of every locomotive, where it is, what service it is performing, and its condition.

Now, how are the Superintendent of Motive Power and Machinery and his assistants to know about loco-

motives that they never get more than a glimpse of, and in regard to the details of which they are necessarily ignorant. Manifestly, in order to know about these locomotives, their utility, usefulness, whether they fulfill the requirements of the service, what repairs and betterments, if any, are necessary, they must derive their information through returns sent them by subordinates and others. With these before them they know, with approximate accuracy, the condition of each particular locomotive and, summing up the whole, of the locomotives in the aggregate. Such being the case the immense value of returns furnishing specific intelligence in regard to every detail becomes apparent at a glance. Through them, those in charge of the department keep in touch with what is going on, and are able to meet all the varied and pressing needs of the service from day to day, and so meet the just expectation of the management and public requirements. The methods employed, indeed, in this respect, are not materially different from those found necessary in all the various departments of a railway. Thus, those in charge of traffic, through the returns they receive, are kept advised of the progress and needs of business. The same is true of the department of accounts; for, from the returns there centered, business is classified and earnings computed, and balances ascertained. And similarly, in the operating department, the reports that reach the head, and so on down the line, are such as to enable the management to wisely supervise operations, safeguard lives and property, and expedite business generally.

The returns of the locomotive department are, as in other departments, the eyes through which those in charge see what is going on. These returns are made by those conversant with the facts and are made to those whose duties require them to know the facts, or

such generalization of the same as the service demands. Operations and needs are thus focused. These returns portray every feature of activity and through them, from day to day, what is going on at far distant points, is distinctly and quickly focused, and such action taken as circumstances require. These necessary and invaluable forms will be found elsewhere herein. They contain full explanatory notes in regard to their purpose and how used. Through them officers know the number of men engaged in working, repairing, maintaining, cleaning, and looking after the equipment; how many engines are available, where engines are needed, how many are in the hospital, when they will be fit for service—information so full and specific that it has but to be studied for the officials to inform themselves effectively in regard to every needed requirement.

This is how Locomotive Supervision in its practical sense is utilized and applied. In this way those in charge of motive power watch the inspection of locomotives, and their general condition and special features, including boilers, fire-boxes, stay-bolts, steam-gauges, safety valves; the location of each locomotive; how each locomotive is employed; the condition of locomotives; those in working order; those needing repairs; those undergoing repairs; the nature of the repairs; when the repairs will be completed; the distribution of locomotives; the particulars and cost of repairs of locomotives; the boilers that have been cleaned; failures in performance of work; the nature (cause) of the failure of locomotives; valve motion; breaking down of particular parts of engines, such as wheels, tires, couplers, driving boxes, brasses, cylinder heads, eccentric fixtures, rods and straps, pistons and rods, valves, rocker shafts, crossheads, crank pins, stay bolts and other

miscellaneous (specified) parts of the locomotive; the mileage of wheels, steel tires, etc.; the wheels and tires that have been removed; the failure of guaranteed parts; the mileage of locomotives; train movements; the switching service; delays of engines; wrecks, accidents; stock killed; actual performance of locomotives; consumption of fuel and oil per unit of service; lubrication; the force employed on locomotives; the hours worked and the wages of engineers and firemen; the force employed in and about shops; their wages; material ordered, how used and quantity on hand; to what accounts labor and material are charged; the tools and machinery at shops; the condition of stationary boilers and shop fixtures; result of mechanical examinations of firemen and others; particulars regarding the employment of the force; its supervision; government, complaints, etc.

This enumeration of supervisory work, while far from complete, is yet sufficient to call attention to the vast number of specific things, every one of which is important, that require the attention of the Superintendent of Motive Power and his assistants; work all important to the economical and effective operation of a property.

Especial attention is called to the different returns —blanks—embodied herein. No one can be advised in regard to the workings of the locomotive department unless familiar with these interesting exhibits. From them he will get more than a glimpse of the practical details that attend the maintenance and operation of engines. He will be able to scan the vast and busy field and so make long and valuable strides toward a personal and practical understanding of its multitudinous affairs. This understanding will be of vast interest and importance to every one connected with the power service; and only less so to the officers and ambitious employes of the operating department,

whose usefulness depends so greatly on the efficiency and co-operation of the locomotive department. Every branch of the service is dependent in a measure, it may be said, on the way locomotives are handled. Much can be done toward securing efficiency in this respect by those engaged in other branches of the service, through co-operation, by aiding the power department where it needs strengthening. But to render such assistance the needs, embarrassments, and vast details of the department must be measurably understood and appreciated. It is the purpose of this book, it may be said, to aid in accomplishing this.

The extent of the motive power department and its many and varied perplexities have only been understood heretofore by those at its head. And this because of its obscure and unwritten features and the technical work of those employed. It is a busy, noisy, mysterious world in fact, even to many who live within its fold. But here, as in other departments of railroad life, general and specific knowledge of its workings will be found to add greatly to its usefulness. For the more people who comprehend the work generally and in detail, the greater the number of men whose energy and ambition will be stimulated, and whose efforts, consequently, will give added force to the intellectual, moral and physical affairs of the department, and, in so far as they do, make out of it all that human ingenuity and effort can accomplish.

CHAPTER II.

DETAILS OF THE ARRANGEMENT AND ADMINISTRATION OF THE DEPARTMENT OF MOTIVE POWER AND MACHINERY.

Of the character, in general and particular, of the work connected with the locomotive plant and the administration of the department, no one who has not had immediate charge of its direction and responsibilities can speak advisedly, or have much to say of practical worth to students and searchers after knowledge in this mysterious and little known field of industry. The subject covers much of general and particular interest in regard to designing of engines, the kind of machines required; inspection thereof; the appliances of engines; location and arrangement of shops and tracks, and the facilities in other directions needed to secure the best results. The modus operandi of overhauling engines that require general repairs; the supervisory work of those in charge of the department; watching shop work; organizing and governing the force generally; discerning what is needed; eliminating extraneous and unnecessary things, form a part of the work of supervising locomotives on a road. For be it understood this book does not pretend in any way to refer to plans or work in the great locomotive manufacturing institutions of the country where these machines are built to sell to railway companies. It refers wholly to the use of locomotives. This feature comes within the particular interest and province of all railway men, but knowledge thereof is confined to so few, that the force as a whole may be said, practically, to know nothing about the organization and conduct of the locomotive department. Fully conscious

of this I have accordingly sought the advice and assistance of an expert in such matters, Mr. Robert Quayle, long a Superintendent of Motive Power and Machinery, and an authority everywhere recognized as pre-eminent, who for a life-time has been in charge of the motive power and machinery of an up-to-date railway. It is not too much to say that he is the peer of the most advanced, conscientious, honest and laborious thinkers and workers in perfecting and administering this great department of railway service. No one can have greater personal knowledge than he of the needs and practices and the economical and effective government of the forces employed. I have been fortunate in this, as I have been throughout all my labors in connection with the discussion of railway matters, in securing the enlightened, progressive and conscientious co-operation of an expert in railway operations.

With this brief and insufficient acknowledgment I will conclude the chapter with what Mr. Quayle has to say in regard to practical details connected with the location and arrangement of shops, and the daily administrative duties of the department of machinery and motive power. What he has written will be of interest and value to all connected with railways—no matter what their position or opportunities to acquire knowledge in this particular field may be.

The question of taking care of the motive power and machinery of a railroad is a problem that requires careful study and thought to maintain it at the standard the service requires; to secure the highest efficiency at the lowest possible cost. When we consider the amount of money paid out annually, that the Mechanical Department is responsible for, we realize that the strictest business methods must be employed to prevent possible waste. For, on a road properly equipped with locomotives, with a sufficient number of shops and

round-houses to take care of the same, nearly one-third of the total amount of money expended annually by a railroad company for operating expenses, comes under the jurisdiction of the Superintendent of Motive Power and Machinery and his assistants. This money is expended for the purchase, care and maintenance of locomotives and machinery; wages of enginemen, wipers, machinists, helpers; fuel, oil and waste. Of these, wages is the largest item. Next comes fuel. Therefore the greatest care must be exercised to see that no unnecessary expense is incurred and no more help employed than is absolutely required; and, further, to see that the greatest economy is practiced in the handling and use of fuel and other supplies.

In connection with the repairs of locomotives, the question comes up as to the proper way to locate shops so as to get the best results; *i. e.*, to make necessary repairs quickly so as to get the locomotives back into the service with the least possible delay, for an idle engine earns no money for its owner. We have to consider whether it is better to have a large central plant, properly located, where all the heavy work can be done; or whether it is best to have a number of smaller plants so located that engines in need of repairs will not have to be taken an unnecessary distance to the shop; for hauling a dead locomotive means that two or three cars less can be handled in a train, thus entailing a loss of revenue to the Company.

In the first place, concentration of shop work means less cost for supervision and therefore consequent lessening of expense. But for a road that extends, say, many miles in one direction, it certainly does not pay to run or haul an engine a long distance, to get it to the main shop. Therefore it is found more convenient to locate smaller shops, generally at division points, to take care of all but the heaviest work. At the headquarters of the road (or better still, at a centrally lo-

cated point) a large plant should be equipped with modern tools and machinery to take care of the repairs that cannot be handled advantageously by the smaller shops. This large plant will, of course, incidentally, receive and repair all engines working within an easy radius of its doors, the same as a local shop, without reference to the extent of repairs to be made.

It has occurred naturally, that with the enormous growth in the size of power, that the smaller shops have not as a rule kept apace with modern improvements in the way of tools and shop facilities; and so are precluded from handling repairs of the modern, large engines advantageously. This will of course be remedied in time, but meanwhile such locomotives must be taken to division shops, or the main central plant.

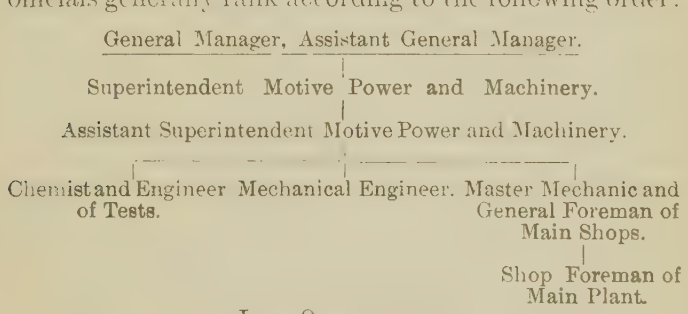
The organization of the Motive Power Department of a road, is a matter that requires thought and care to bring and keep up to the high standard required, for a road soon obtains an inevitable notoriety if its service is not good; and with competition in the business, other lines prosper through such neglect to provide prompt and adequate service.

In direct charge of the small army of men employed it is absolutely necessary that at the head of the Power Department should be a man who has had years experience and who knows just how everything should be done. He must be a natural leader of men, as the antagonizing of employes, consisting as they do of a variety of trades, nationalities and dispositions, is fatal to success. It is remarkable the discrimination possessed by men, and a superior who treats everybody with kindness, firmness and fairness, can be assured of the good will and services of his subordinates, a thing essential to his success.

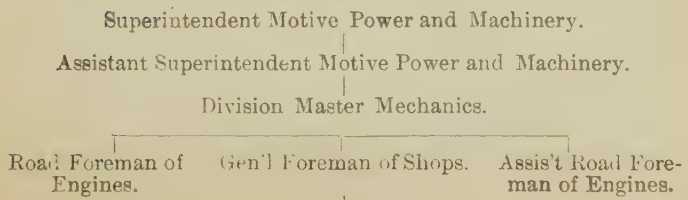
The method of classifying Motive Power Department officials varies on different roads. In some cases

the Superintendent of Motive Power is equal only in power and authority to a master mechanic. Whereas, on other sysems, where the mileage is great and under one management, a General Superintendent of Motive Power is usually employed, who reports direct to the General Manager or a Vice-President. In such cases the superintendents of motive power and machinery report to and take orders from the General Superintendent of Motive Power and Machinery. In this case the latter official is entirely independent of the ordinary operating officials. On other roads the Mechanical Department may be practically under the control of a General or Division Superintendent.

This arrangement, however, is not practically the best, for the expert in such cases has often to do business with and take orders from men who are not familiar with mechanical matters. The most satisfactory method of handling the department is shown where the officials generally rank according to the following order:


General Manager, Assistant General Manager.
Superintendent Motive Power and Machinery.
Assistant Superintendent Motive Power and Machinery.
Chemist and Engineer of Tests.
Mechanical Engineer.
Master Mechanic and General Foreman of Main Shops.
Shop Foreman of Main Plant.

LINE ORGANIZATION.


Superintendent Motive Power and Machinery.
Assistant Superintendent Motive Power and Machinery.
Division Master Mechanics.
Road Foreman of Engines.
Gen'l Foreman of Shops.
Assis't Road Foreman of Engines.
All Shop and Round House Foremen.

The question when to shop an engine is one that requires a good deal of attention on the part of the Superintendent of Motive Power and his assistants. Should an engine be taken in for General Repairs, which may cost from $1,200.00 to $1,800.00, when, by making light repairs and putting it into suitable service, much more work can be obtained from it? Or the reverse? It can never be best to keep an engine in service when it is doing work in an extravagant manner, causing failures, and not only delaying its own train, but others that may be on the road. Each particular case has to be decided, however, according to circumstances, and to obtain results at the least possible cost and embarrassment to the service; and when saying this, we have to consider all departments concerned. An engine can be kept in service for so long a time that the cost per mile run will apparently be low, but at the same time while getting over the road, it may not be hauling full tonnage, and the cost per ton mile will really be very high.

As already stated, engines requiring heavy boiler work, or those on divisions adjacent to the main shops are taken care of there, but a large number have to be given repairs at the smaller shops.

On divisions where the water used by engines is good, little or no boiler work is necessary and an engine can be kept in service for two or three years, by doing what small amount of work is needed to the machinery at intervals. The mileage in such cases often runs up to 150,000 or 200,000 miles; but on divisions where the water is strongly impregnated with scale forming matter, the department is kept busy trying to get mileage enough out of engines before shopping them, to satisfy the Superintendent of Motive Power and Machinery. On such divisions as these, it is nothing unusual for a new engine to require flues reset after four to six months' service, and at the expiration of eight to ten

months (or before the engine has made 50,000 miles) new half side sheets are often necessary. This work, done at a small shop, will keep the engine out of service for thirty days or more; while at the main shop such work, which comes under the head of general repairs, can be done in eighteen to twenty days by the aid of modern tools and machinery, thus cutting down the time the engine is out of service. This is a matter of great importance, especially at a time when business is heavy and engines are in demand to keep cars moving.

The question of purifying water that is laden with sulphate and carbonate of lime has been given much attention. The old-fashioned method of trying to make a locomotive boiler into a "water softener" has given way to the more common sense method of treating the water in suitable tanks prior to being put into the tender; and this with good results. In some cases, engines consigned to the shops, that have been using the untreated water, are kept in service 60 to 90 days longer by using treated water entirely.

The designing of locomotives so as to get the most satisfactory service out of them, is a matter that requires more than ordinary care and attention. In accomplishing this the Mechanical Engineer submits his ideas on paper, after finding out what is required, and this is carefully examined by the Superintendent of Motive Power, so as to see that the weight on drivers is not greater than the Engineering Department will allow on its structures; also that the heating surface is properly proportioned to the size of the cylinders, and that the power exerted by the cylinders is sufficient to utilize all the adhesion given by the weight of the locomotive on the driving wheels.

It is also a matter of great importance to utilize parts that are standard on a road so far as possible. The question of bearing surfaces must also be looked into carefully, as an engine that runs hot on account of ex-

cessive pressure per square inch on the journals, is obviously unsuited to the service. Again, if through faulty design, the engine does not make steam freely or cannot make time, the department is justly called to account. So it will be seen that each part has to be gone over on the drafting board, to be sure that it bears its proper relation to the other parts and to the whole machine.

An important part of the Draughtsman's business is to so design the locomotive that the parts that need renewal frequently are easily accessible. Bushings for brake rigging, rocker boxes, tumbling shafts, cylinders and so on, are a step in the right direction, as they enable repairs to be made at small cost. By their use the various parts are kept standard size much cheaper than they otherwise could be—bushings being kept in stock instead of the whole part.

Between engines of somewhat similar capacity, there should be as little difference as is consistent with the design. This means a large reduction of material in stock and a consequent reduction in the number of special tools for finishing same. Grates, small brackets, brake heads, driving boxes, springs, wheel centers, crank pins, etc., can, with very little planning in such cases, be used interchangeably to good advantage. By living up to the dimensions as shown on the working drawings, a standard can be maintained which will enable changes to be made at small expense. While it is a good plan to invite suggestions from the men handling the engine on the road and in the round house, a change of design in any part should not be made without getting authority from the person charged with this duty; for if a change is a good thing at one place it is good at another; and the drawing should be revised to show the improvement so that it may be generally embodied in any repairs that are to be made to the part or parts affected.

The Drawing Office plays an important part in the railroad world, for here the locomotive is born. The Mechanical Engineer is the head of this office, under him coming the Chief Draughtsman, and such assistants as are necessary to do the work. The duties of the Mechanical Engineer are varied. To-day he will be busy designing a locomotive—to-morrow engaged upon plans for new shops, and the next day figuring upon a proposed electrical installation. He is expected to keep in touch with all shop improvements, new designs of power, etc., and be able to answer any and every question that may arise, from the power required to move a turn-table to the amount needed to drive a shop with its various tools and machinery. The care of all drawings, blue prints, etc., is entrusted to the Chief Draughtsman, who must be methodical, filing everything so that it can be found at a minute's notice.

The patterns for cast and malleable iron, brass and steel, are under the jurisdiction and care of the drawing office; and it is the duty of the Mechanical Engineer and his assistants to so design their work in their patterns that the greatest strength necessary will be forthcoming without undue weight. Thus, an unfinished casting should only have enough stock in it to finish up properly with a minimum amount of machine work.

When there are many locomotives a dynamometer car will be found advantageous to determine some of the problems that cannot be got at any other way with any degree of accuracy. This car is usually fitted with properly designed and calibrated draft rigging, so that when connected to the rear tender draw-bar, the exact pull of the locomotive can be determined, and by a series of levers and pointers, this information is transferred and drawn on a paper, which is made to travel at a certain speed. A clock connected up electrically, makes a mark on the paper every ten seconds and a

push button operated by an assistant is used to move a pen which makes a mark on the paper at each mile post, so that at a glance the speed can be told. Air, steam and other gauges are used to determine the pressure carried, and generally in connection with this apparatus an indicator is applied to the engine, by which the performance of the steam in the cylinder is plainly shown.

This work is usually done under the direction of the Mechanical Engineer, apprentices being used to get the data, and work it up to show the efficiency or inefficiency of the locomotive.

Another important branch of the Mechanical Department is taken care of by the Chemist and Engineer of Tests, whose duty it is to test the various metals, etc., and see that they come up to specifications. Steel for boilers is closely inspected before being accepted for use; steel castings are examined to see that they are free from flaws, checks or blow holes; lenses for signal lamps of all kinds have to pass a rigid test; and torpedoes which are used as a danger signal are exploded (a few from each shipment taken hap-hazard), as a check on the manufacturer. Rubber goods and the other appliances in use on a railroad are also subjected to minute inspection before the Engineer of Tests will accept them. By this means poor material that might get into the locomotives and cars and cause trouble, is discovered and rejected to the great good of the service.

The visiting of shops along the line is something that the Superintendent of Motive Power and his Assistants must do to keep in touch with what is going on. On a large road, this will be a matter of considerable difficulty within reasonable time on ordinary train service. This difficulty is overcome through the business courtesy of the Operating officials who have to make trips that extend to all parts of the system, inviting

the official in charge of motive power to accompany them. They thus have opportunity of meeting the Master Mechanics, Foremen and Division Superintendents, and of observing the service and hearing any complaints about the motive power, or suggestions for improving it. The Road Foremen and their Assistants also come in for a share of attention, while inspecting the road, and thus many things come up which benefit all concerned.

When matters of general importance have to be transacted, a meeting of the Master Mechanics is called, who journey to headquarters, and there talk over the matters under consideration, and thus an understanding is obtained. Afterwards the Master Mechanic on his return home, will get his foremen together and give them instructions as may be necessary.

It is the general rule on roads to promote Firemen when competent, to the position of Engineer, and all new firemen when hired, are required to pass a physical examination, so that defective eyesight, color blindness or other defects may be detected. After satisfactorily passing the examination, the fireman is put to work and provided with a book containing information pertaining to his duties in the economical operation of an engine, which interrogatories he is required to answer after being in service twelve months. At the expiration of that time, he is given the second year's book which contains information of a more advanced form, and an examination is given him at the end of the second year. He then gets the third year's book, which covers more fully the points that he should understand.

Before becoming an engineer, at the end of the three years, he must pass a time card examination before the Division Superintendent and a medical examination before the Company's Surgeon. If he passes these successfully, he is sent to headquarters before an Examining Board, consisting of Road Foremen of

Engines, and the Air Brake Instructor, who put him through a written and oral examination. If he answers correctly eighty per cent of the questions (air brake and mechanical), he is reported to the Master Mechanic as a full-fledged Engineer. He is then used on Switch engines and unimportant freight trains for the first year, after which he is entitled to full pay; but even then is not allowed to handle a Passenger train. Three years' service as an engineer is required before this, the goal of all young engineers, is reached. Thus every safeguard is thrown around the service and the public, before the embryo engineer is allowed to handle an engine.

Let us now look at the main shops and the arrangement of them and the tools and machinery they require. From six to ten per cent. of the engines in use on a road will generally be undergoing repairs, so that with the help of the local shops, the principal plant should be able to handle from 35 to 45 engines per month, depending of course on the number of locomotives, the condition of the power, and whether the demand for it is great or not.*

In deciding upon a location, the endeavor should be to pick one having clean and reputable surroundings, a level, high piece of ground where good drainage can be obtained, with perfect accessibility from all sides so as to be able to handle things more economically and quickly than otherwise would be the case.

In choosing land there should be taken into consideration the possibility of growth, which on many railways is very rapid, so that many Superintendents of Motive Power and Machinery have been cramped for lack of room, which could at first have been obtained cheaply. Having decided upon a location, the best layout of

*This estimate is based on an equipment of 1,200 locomotives. It should, therefore, be lessened or enlarged according to the circumstances of the case.

shops must be secured so as to get an engine through them with as little delay as possible. Plenty of room inside and out, costs money in the first place, but pays on account of the increased facilities for getting about and not having one thing buried and perhaps lost by other things being put on top of it. The larger the shops the greater the possibility for good arrangement: and the better the arrangement the better will be the method of getting out the work, with a consequent reduction in cost.

Outside the shops should be a series of tracks connected with a transfer table, for the storing of engines that have been brought in for repairs. One track should be used for getting engines out of shop, putting the tenders behind; and another be available for pushing engines in, so that the two operations can be going on at the same time. Much controversy has taken place as to the best kind of erecting shop, and there are advocates of the two kinds generally used. The one with a large number of stalls at right angles to the main building, fed by a transfer table with an overhead crane for wheeling and unwheeling, having as many advocates as the one where from four to six engines stand on a single track, the tracks paralleling one another, each containing as many engines, traveling cranes of suitable capacity being used to get them from the in-going track to a vacant place, and after repairs have been made, lifting them on to the out-going track. We will use the former plan in the proposed shops, as it is the one most generally adopted in America.

With an output of thirty-five engines per month, there should be thirty stalls available, as it would be possible, providing the machines were capable of doing it, to increase the number of engines turned out to fifty per month, if occasion required it.

Plenty of room should be allowed on each side and in front and back of the largest locomotive so that men can do their work without interfering with each other, and the flues taken out and put in, without the necessity of having doors opened, as is sometimes necessary. The storage of parts taken from locomotives in shops, that do not need repairs, is a matter that should be given consideration. In some shops these parts are stored in pits each side of the engines, having heavy covers over them. Another plan is to have a lean-to (addition) outside of the shop where racks are provided between tracks. This latter method is probably the better one as the parts are always in view of the foreman and men, and are not so likely to accumulate as in a pit. A double track, electrically driven, high speed transfer table, of sufficient length to take an engine and tender on it, will provide ready means of quickly handling engines and supplies in and out of shops.

The erecting and machine shop should be combined and provided with a good system of electric cranes to move the parts taken from the engines, after having been boiled in a lye vat conveniently located, to the machine that is to do the work on it. The ideal way is to place all the tools so that an extra handling, or a backward movement, will not be necessary. The various parts when handled by more than one machine, should go in at one end rough, and come out at the the other end, finished.

The machine side should have a gallery in which all of the light work, such as air brake material, brass work, bolt making, etc., is done. The machine shop, proper, should be divided up, and in one half the heavy tools located, and direct motor driven, with high speed single track ten ton cranes over them to facilitate the handling of material. The blacksmith and forge shops should go together, and be so located that

heavy frames and forgings can be conveniently handled to and from the erecting shop and to the machines.

The complement of the blacksmith shop should consist among other things of a 1,500 pound steam hammer for general work, and a 3,500 pound hammer for frame work; while for axles and heavy forgings, one not less than 6,000 pounds should be provided. Forging machines for turning out standard work should be used whenever possible and grouped together. A blast fan in duplicate and direct driven either by motor or engine, and not connected with any other machine, should furnish a pressure of eight ounces for the fires.

The boiler shop should be combined with the tank shop, and suitable cranes for quickly moving boilers and tanks, will help to increase the output. The tin shop and pipe shop should also be together under one foreman, and should be a very large roomy shop on account of the material and work done in this building being bulky.

The gray iron and brass foundry should also be together. The paint shop should stand by itself as it is generally used for painting tenders only. The painting on the locomotive should be done in the shops while repairs are being made, to economize time.

The storehouse is one of the most important factors in getting power into service promptly. By locating it centrally, it can be readily reached from each of the shops, and thus a large amount of valuable time saved. A telpher system can be employed for handling medium heavy material with very good results.

As all of the shops and buildings mentioned use power, light and heat, it is very essential that an economical plant be installed to furnish these. With electrical power-transmission, cranes, etc., and a suitable lighting system such as would be necessary for a plant of this size, a large amount of current has to be furnished, and two generator units, each able separately

to run the plant should be provided so as to take care of repairs, emergencies, etc.; while for night loads, a smaller capacity unit could be used to good advantage. As a large number of pneumatic tools are used in most up-to-date shops, it is very necessary to have air compressors with a capacity amply large for every emergency. Probably the best results can be obtained by having two air compressors, each with a capacity of 1200 cubic feet of free air per minute. In case of a break down there would be something to fall back on, and still leave room for growth.

A high pressure water system for fire protection should be installed in the power plant, and pumps for taking care of accumulator in boiler shop, etc. The exhaust steam from engines, pumps and air compressors, should be used for heating the numerous buildings; which can thus be done economically.

To furnish steam, a battery of boilers, fitted with automatic stokers and chain grates, and coal and cinder handling machinery, will enable the plant to be run at a minimum cost for labor and fuel used, that could not be successfully done in a hand fired furnace.*

We will now watch an engine in its progress through the shops. It has arrived on the "Hospital Track" and the Master Mechanic from whose division it came, has sent forward a report of work necessary to be done. This report is turned over to the General Foreman, who in turn gives it to each of the foremen so they may note the work they are called on to do, and so

*What is said here derives added interest and importance from what is said in other parts of the "Science of Railways" in regard to matters relating to locomotives and the machinery and shops incident thereto. This brief treatise or resume, however, is of immediate interest, affording further insight into what is occurring in this great field of industry. It also affords an interesting exposition of results as to the growth and perfection of the appliances devised by those connected with the department of Motive Power, who have studied it to the great benefit of railways and to the great profit of those who own these properties.

get ready. We will suppose that the engine needs a new firebox and what is known as general repairs. The first move is to take the tank from engine and put it in the tank shop for repairs, the engine meanwhile being placed in stripping shed where all of the rods, links, eccentrics, air pump, driving brake, material, etc., are removed and placed in a lye vat to have the grease boiled off from them. The next move is to the transfer table, from which it is hauled by a windlass or drum with cable into a vacant stall, and immediately the overhead crane with double crab, lifts it bodily, so that the wheels may be rolled from under; after which it is lowered upon specially designed trucks, so that if necessary it can be moved along the track.

The boiler is lifted out and sent to the boiler shop, and the frames with cylinders left, for the mechanics to work on them; the parts from the locomotive are distributed to the various men or machines which work on them; the wheels are sent to the lathes for tires and journals to be turned up; the driving boxes to be fitted with new brasses, shoes and wedges, after being "laid off" are given to the planer hand; the eccentric straps and liners are turned up and closed; rocker boxes, valves, links, pistons, etc., etc., are taken to their respective place for repairs, the side and main rods being at the same time taken care of, and the brake rigging overhauled. As far as possible, all of this work is specialized, among men who have become experts in such matters.

On going to the boiler shop to look for the boiler of the engine, we will find that rivets have already been cut off back head, in readiness for the new firebox that has probably been made before the engine arrived in the shop. Flues are being taken out and all is hustle and noise, the pneumatic hammers making talk difficult and hearing impossible for an outsider. When the flues are removed, they are taken to a rattler,

which in causing them to revolve and drop against each other quickly breaks off the scale. From here they are taken to a machine which cuts off each end and then a piece is fitted in and welded up to the flue so as to make it the same length that it was before. After testing, they are ready to go back to the boiler, where the back boiler head has been removed, the stay bolts broken off and mud ring removed. After this is done the old firebox can come out and the new one take its place. When properly located, the holes to receive the stay bolts are tapped out, stay bolts run in, and mud ring and staybolts riveted up.

By this time the flues are going into the boiler, and after being fastened in flue sheet by expanding and beading, the boiler is ready to be tested, and if any defects exist they are remedied before it leaves the shop.

Let us now go back and see what is being done on the other part of the engine that was left in the erecting shop. We will find men facing up driving box jaws, prior to shoes and wedges being fitted, and other men will be boring out cylinders, and fitting up eccentrics and straps and driving boxes on the wheels that belong to the engine.

The spring rigging will be put in shape and everything moving, so as to be ready when its turn comes to be assembled. A glance into the tank shop will show that the tank is about ready to come out and go to the paint shop. We will find that the tender boxes and wheels have been put in good condition, and that the tank proper has been tested for leaks and the frame overhauled.

Meanwhile, the tender has been hauled on to the transfer table, and from there goes to the paint shop where it is cleaned, rubbed down and painted in readiness for the arrival of the engine from the shop. We will take another look into the erecting shop and will

find that the boiler has arrived from the boiler shop and the crane has picked it up and set it down upon the frames. Work now goes along very rapidly. The engine is raised and wheels run under it, after which the shoes and wedges are put in, binders applied, links and eccentric blades put up, guides hung, main rods applied and valves set. To do this rollers are placed under main driving wheels, or wheels having eccentrics on them and revolved, and with proper knowledge and the necessary tools, the valves are set so as to give the best results in the service.

The boiler is now filled with steam from the power plant, and again tested, after which the throttle valve is opened and as the front cylinder heads and pistons have not yet been put in place, the steam rushes from the boiler, through the dry and steam pipes and passages, out of the cylinders, carrying with it any foreign material that may have accidentally been dropped by the men while doing their work. During the time this work has been going on, painters have been busy and the engine begins to have a finished appearance. The side rods are put on, pistons and cylinder heads applied, pilot fastened in its proper place and the rest of the painting done. The engine is then taken out and tender put behind it. After getting coal and water we are now ready to break it in, *i. e.*, run it under steam to see that the various parts run smoothly and cool; after which it is ready for the particular service it has been assigned to.

Such briefly are the methods adopted with the engines that pass through the shop. Some, of course, will not require such extensive repairs as those mentioned, while others will require more. But whatever may be necessary, system and orderliness, it is apparent, will accomplish more satisfactory and economical results than can otherwise be attained.

CHAPTER III.

AIDS USED IN SUPERVISING THE OPERATION AND MAINTENANCE OF LOCOMOTIVES.

The Supervision of locomotives by the Mechanical Department, and especially keeping the Master Mechanic and Superintendent of Motive Power advised, is rendered practicable and effective by the use of returns covering all the various phases connected with the operation and maintenance of locomotives. Let us consider these in connection with the purposes they serve. Each will be found to be of importance and necessary to a correct understanding in regard to locomotives particularly and as a whole, and therefore, of interest to all who have anything to do with locomotives.*

WASHING OUT LOCOMOTIVE BOILERS.

NOTE.—The form used in reporting locomotive boilers washed out is shown in detail, M. P. Form 1, Appendix.

To the Motive Power Department there is nothing which gives such large returns as the successful carrying out of the instructions issued relating to the proper cleaning of boilers.

The report thereof is intended to call the Master Mechanic's attention to the fact that certain boilers

*In the preparation of what follows I am indebted for the advice and assistance of Mr. Robert Quayle and other experts in matters relating to the Supervision of Locomotives.

have been washed out, as per instructions, on a given date. He knows how often these boilers ought to be thoroughly washed out in the district through which they run, and he can glance down the columns each week and find out how many times each engine has been washed out. This, of course, will call to his mind the instructions issued, namely: that they use a given sized pump that will give them a certain pressure, say not less than 100 pounds per square inch. It will also call to mind the fact that they should use the facilities placed in their hands for this work; namely, the long and the short and the crooked nozzles. The Master Mechanic knows that if the plugs that are put into the boiler are periodically removed and first the short nozzle is put in from the front end of the boiler into the flue sheet; and then a longer one; until the longest one is put in; and they have in this manner carried all the scale that has been washed off the flues and crown sheet back to the leg of the boiler; and then, by the rods that are used through the hand-hole plates around the leg of the boiler, they work all the scale formation down to the mud ring, and wash it out with high pressure (anywhere from 100 to 150 pounds per square inch)—the Master Mechanic knows that the boiler, by these methods, ought to be and is clean. In addition to this, however, the Master Mechanic should have his subordinate officers so instructed that they will not only have the men who are doing this work well informed as to the methods of doing it, but he should see to it that they carry out the instructions to the most minute detail, as it is essential that the instructions are so carried out.

The proper washing of boilers removes the scale in the boilers, and thereby gives the flues the largest possible chance of conducting heat to the water, and this, in turn, enables the water to absorb the largest number

of heat units possible under the existing conditions, per pound of coal.

LOCATION OF LOCOMOTIVES.

NOTE.—See M. P. Form 2, Appendix, being the Master Mechanics weekly report to Superintendent of Motive Power and Machinery of the the location of locomotives.

One of the requirements of the Master Mechanic is to have on his desk, (or better still, in his pocket) a report that gives him the location, kind of employment, and condition of every engine on his division.

He should have these engines classified and know how many he has of each class, where these engines are employed, and the kind of service they are engaged in; and he should also include in this report the number of engines in the shop, when they went into the shop and when he expects them out, and the class of work being done on these engines while in the shop.

By referring to this report and also to his report on condition of power (form 5), he is enabled to determine what power he can spare if called upon by the Superintendent of Motive Power for other engines, and to know what engines he has coming out of the shops.

When desiring to know what kind of an engine he has running on a certain train between certain points, he can tell at once from this report without any further investigation. Every Master Mechanic will find this a very useful report to have with him constantly

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KEEPING TRACK OF THE LOCOMOTIVES OF EACH CLASS IN SERVICE ON THE DIFFERENT DIVISIONS.

In order to facilitate the most economical and effective distribution of the power possible under the changing conditions of traffic, the Superintendent of Motive Power and Machinery should each week send to the

general officers in charge of the Operating Department a report showing the number of locomotives of the various classes in the different kinds of service on each division of the road.* Thus they will have before them the total number of engines in passenger, freight, construction and switching service, as well as those that are not in service; also the reasons why the latter are tied up—some in the shop, some waiting to go into the shop, others that have come out of the shop and are waiting for service, and, further, those being limbered up for service. If engines are leased or there are vacant numbers (for engines that have been cut up,) these are facts are also shown, so that the general officers can, by a glance at this report, see just what the conditions are. It gives to the Superintendent of Motive Power, as well as to the operating officials, an idea of the available power and calls the attention of the general officers, in busy times, very strongly to the fact that they either have enough power, or that they ought to have more power to do the business. This report, taken in connection with the weekly report of mileage in each kind of service on each division, gives to the Superintendent of Motive Power, as well as the other general officers, information that will enable them to transfer power from a division where business is not so heavy and place it on other divisions where it is needed more.

CHECKING THE REPORTS OF LOCATION OF EACH LOCOMOTIVE.

In order to see that no locomotives are omitted from the Master Mechanics' reports showing the location of locomotives, a special blank is used by the Superintendent of Motive Power and Machinery in

*See M. P. Form 3, Appendix.

checking up the numbers of the engines reported.* The importance of this blank, at first glance, may not be thorougly understood, but with the following explanation it will be seen that in the office of the Superintendent of Motive Power and Machinery it is a very interesting and useful record. On this form a separate space is provided for each locomotive, and after entering in the proper spaces the notations as to the location of the various engines included in the different reports, the vacant spaces in the form will represent the numbers of the locomotives for which no reports have been received, and the matter can then be taken up with the person who, according to the last report, should have included such engine in his report.

Division Master Mechanics, when they make their weekly reports, may forget that one or two engines have been cut up on their division; they are likely to forget, also, that they have one or two engines tied up at some remote point on their division, waiting for repairs in some out-of-the-way round-house. They may not remember that three or four of their engines were sent to some neighboring division shop for repairs, and therefore do not report them, and the Master Mechanic in whose shop the engines are does not report them because they are not his engines. Hence the necessity of having an audit system in the office of the Superintendent of Motive Power that will check up every locomotive on each division by its individual number each week.

The blank can be used for any number of divisions, and can be made for any number of locomotives by enlarging the form. As illustrated in this volume, however, it can be used for fourteen hundred locomotives, and a simple glance at this report will show the location of any engine on the system.

*See M. P. Form 4, Appendix.

This same form may also be used for the purpose of checking up other locomotive reports received from Master Mechanics, such as the monthly report of inspection of fire boxes, stay bolts, and so on.

CONDITION OF LOCOMOTIVES.

In order that a railway may be successfully operated, the first requisite is motive power in good condition. Each Master Mechanic should know the condition of every engine in each kind of service on his division, and the Superintendent of Motive Power should have a report from every Master Mechanic each month, showing this information for each division.

Unless the Master Mechanics and the Superintendent of Motive Power are in possession of the actual facts as to the condition of the power, they are not in position to maintain the required standard of efficiency. They must know what is necessary to be done before they can do it.

The report as shown in the appendix (M. P. Form 5) has this object in view. It gives the number of each engine, the size of the cylinders, and two of the most important items in connection with the requirements of the engine, namely: the date when the engine had last general repairs and the mileage made since that time. When the officers of the Motive Power Department have this before them, they can determine quickly and accurately when the engine will need to go in the shops. When they know the work performed by an engine on the division over which it runs, and the mileage it has made, they can readily determine whether the engine will have to go in the shop in thirty, sixty, ninety or more days.

This report also shows the condition of the engine's machinery, flues, fire-box, boiler and tires. On some divisions where the water is bad, the flues may have to

be renewed, or, at least, a portion of them; and the report would then show machinery good, flues poor, and would also show the condition of the fire-box, boiler and tires. If the fire-box, boiler and tires were good, they would know at once that the engine simply needed to have flue work done, which would take only a short time.

The Superintendent of Motive Power, by this report, is constantly kept advised of the real condition of the power, and from it he determines whether he ought to increase or decrease his force in the shops, or whether he ought to work longer or shorter hours.

To aid the Superintendent of Motive Power and Machinery in determining the proportion of the total number of locomotives on each division in good, fair, and poor condition, or undergoing repairs in shops, a form is provided for his use in summarizing the Master Mechanics' monthly reports showing the condition of every engine on each division.*

In compiling this report the passenger engines are first entered in numerical order, according to condition, and then the percentages of such engines in good, fair, and poor condition, as well as those in the shop, are determined. Similarly the relative condition of locomotives in freight and switching service is ascertained and finally the percentages of all the locomotives (passenger, freight and switching) in good, fair and poor condition, and in shops.

The Superintendent of Motive Power knows how far he can let the percentage run down the scale before he has to begin to get the power in better condition, and he furthermore knows how far he will be able to let the percentage of power go up the scale before he will find it desirable to cut down expenditures on such work.

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*See M. P. Form 6, Appendix.

For the information of the General Manager and others concerned, a digest of the foregoing reports (5 and 6) is prepared each month by the Superintendent of Motive Power and Machinery.* They are thus kept advised as to the kind of power, as well as the number of engines in each class, assigned to each division of the railway, and it puts before them such facts as they need. It is their business to know whether the power is being properly utilized; whether there are a number of small engines on a large division where larger engines should be employed, and so on. It gives them an opportunity to check up the Motive Power Department and the division officials, to see that the power is everywhere being used to the best possible advantage. It furthermore places them in touch with the condition of the power, and they can determine whether the Motive Power Department is doing its duty in keeping up the power in each kind of service. It also gives the information that is necessary in order to see that the freight power is not being maintained at the expense of the passenger power or vice-versa.

This report also gives a very comprehensive idea of the work done by the shops during the past month, by showing the number of engines in each kind of service that have received general and heavy repairs; in short, it is a summary of the work performed by the shops during the previous month, as well as a summary of the location and condition of the power. All in all it is a very valuable report for officials to have before them, whether they are in the operating or mechanical department.

REPAIRING LOCOMOTIVES.

Whenever an engine is sent to the shops for repairs, a statement of the work necessary to be done should be made for the information of those having

*M. P. Form 7, Appendix.

such work in charge. To reduce to the minimum the clerical work necessary in indicating the needed repairs a blank has been provided on which all the various parts of the locomotive are listed in order, and numbered.* Then whenever a new part is to be subtsituted for the old, the letter "X" is entered opposite the number representing that part; or if the old part is to be repaired, instead of being renewed, the letter "O" is used. For example, No. 1 represents the boiler; if a new boiler is required, the letter "X" should be placed immediately before the word "Boiler." If the boiler is to be repaired, the letter "O" should be placed before it, and then the kind of repairs noted opposite each term; thus, if the boiler braces are to be repaired, the letter "O" would be placed before that part; if the left side sheets are to be repaired, the letter "O" would be placed there; if renewed, the letter "X" would be used, and so on.

When the Master Mechanic receives this report, he ought to check it over carefully. He should have it compared with reports of recent work done on the engine, and if, for example, he finds the injectors were repaired within a week, he should ascertain why they should be repaired again when the engine goes into the shops. If the letter "O" is entered opposite "air-pump," and he finds that the air-pump was put on during the last week, he should make inquiry at once to know why the fact that the air-pump had been repaired was overlooked, or if the repairs are necessary, why they are needed so soon.

In connection with this, the Master Mechanic should also see how much mileage this engine has made since its last general repairs, and determine whether, in his judgment, the work performed by this engine is such

*M. P. Form 8, Appendix.

as to warrant its going into the shops at such a time; he also determines whether this engine ought to have heavy, light or general repairs.

The principal object of this report is, first, to see that all the work that is necessary will be done while the engine is in the shop; and, second, that no work will be done on the engine that is not necessary. When the engine goes into the shop for general repairs, the shopmen may not know what work was done on the engine during the last thirty days, and much of the work might be done over again if their attention was not called to it by a report of this character.

Also, an outline of the work contemplated on each engine will enable the various shop foremen to plan their work and provide for the materials which will be needed, so that there will be no unnecessary delay in the course of the engine through the shops.

The Superintendent of Motive Power should have these reports carefully examined and if there are any irregularities in them, they should be sent back for correction at once; this will have a tendency to make every division official see to it that work is not requested to be done unless it is, in his judgment, absolutely necessary in order to put the engine in proper condition.

In addition to being used to indicate in advance the repairs thought necessary in each particular case, this form is also used after the completion of the work as a record of the repairs actually made.

In connection with the foregoing blank (8), there are several others which are used by the foremen in charge of the different repair shops, viz.: forms 9, 10 and 11, as See appendix. Form 8 embraces all the parts of the locomotive, and is a summary of the work done in all of the shops: the three other forms each cover the

repairs made in a particular department or shop, the parts of the locomotive, as listed on each blank, being such as will be repaired or renewed in the shop for which the form is designed.

For example, on form 9, it will be noted that the numbers from 1 to 33, inclusive, with one exception, represent boiler-shop work, and the exception is No. 18 (the testing of the boiler), which is looked after in the machine shop. It will also be noted that the numbers 34, 35, 36, 37 and 38 (representing the ash-pan and damper work), are omitted from this form, because this work is done in the sheet iron shop, and the grates are placed in the fire-box in the machine shop. Thus it will be seen that the parts listed on each of these reports are those corresponding with the work done in each shop.

The object of these reports is to save clerical work on the part of the foremen, as all they have to do is to place the letter "X" or "O" after the number which corresponds with the item of repairs as shown on form 8; for example, take the last number, 137, on form 9; if they put the letter "O" after that, it would mean that the quadrant was repaired. If they placed the letter "X" after number 137, it would mean that the quadrant was renewed

These forms, however, may be changed to suit the plan of doing work in other shops, and when those using the reports become accustomed to the numbers, it is a very easy and simple way to keep a record of the work performed.

THE COST OF LOCOMOTIVE REPAIRS.

In order to ascertain the cost of material and labor expended for repairs on a particular engine at a certain shop, the Master Mechanic should promptly notify the

storekeeper or other person in charge of the accounts at what point the repairs will be made and the date the engine entered the shop, so that the storekeeper can keep the expenditures thereafter on account of that engine separate from the ordinary repairs the engine received while in service.

When the shop work is completed on this engine and it is ready for road service again, the Master Mechanic should send another notice to the storekeeper, advising him that the work on the engine in the shop has been completed, and that from that date the cost of material and labor expended on account of said locomotive is not chargeable to the shop repairs. The storekeeper should then compute the cost of the repairs, including labor and material, and enter the amounts in the spaces provided in the form, sending one copy to the Master Mechanic for his information, and retaining one for a record in his own office. The same form of report may be used by the Master Mechanic in advising the storekeeper regarding the locomotive, and also by the storekeeper in reporting to the Master Mechanic the cost of the repairs during the period designated.* This report need only be required when the amount expended for repairs exceeds a certain amount—say $25.00.

SUMMARY OF LOCOMOTIVE REPAIRS.

In order that the Master Mechanics and the Superintendent of Motive Power may keep advised of the work being done at the different shops, a summary should be made of the detailed reports of locomotive repairs, so as to show briefly and in convenient form the general nature of all heavy repairs and the length of time each locomotive is in the shop.†

*M. P. Form 12, Appendix.
†M. P. Form 13, Appendix.

The Superintendent of Motive Power should see that such a report is received from every Master Mechanic. These reports place before him at once every engine on the system that is undergoing or requires heavy repairs, and by ascertaining from the previous month's reports the number of engines he was able to turn out of the shops, it enables him to see whether or not he will be able to keep up with the demands upon his shops.

This summary should also show the locomotives on the division which were out of service on the last day of the month, together with the reasons therefor; the number of engines undergoing repairs; those that are waiting for repairs—on side-tracks or in round-houses —and the engines in each shop.

If the Master Mechanic is not able to keep up the condition of the power on his own division, this report will point out to him the necessity of asking the Superintendent of Motive Power to have some of his engines put through other shops on the system.

LOCOMOTIVE REPAIRS AT GENERAL SHOPS.

On account of the volume of work done at the general shops, it is important that the foregoing reports should be supplemented frequently by further reports showing from time to time what locomotives are undergoing repairs in the general shops and noting the progress which is being made on same. The form of report illustrated in this volume (M. P. Form 14, Appendix) is a most excellent report for every man in the Motive Power Department to have, as it shows each week the total output of the shops, the number of engines in the shop, classification of each engine, the division from whence it came, the date it was received at the shop, and when it will be out.

If engines of a certain class are needed on a particu-

lar division, by consulting this report it may readily be seen whether or not one of this class of engines is in the shop, and when it will be out.

It will be noticed that on this report the boiler shop work is classified, the kind of repairs being designated by a letter, so that, for example, if engine 100 needs a new fire-box, it will show "100 A;" if, in addition to that, it requires a new wagon top, it will show "100 A H," etc.

This report indicates to the Superintendent of Motive Power the ability of the boiler shop to keep up with the other shops. For example, if the boiler shop has been getting out, during the last month or two, nine or ten engines with new fire-boxes, and there are twenty waiting for such work, it is very evident that the force or facilities in the boiler shop should be increased to meet the requirements.

This report also gives the number of engines that are to be limbered up during the next week, and a glance at this gives the Superintendent of Motive Power an idea at once of what will be available in a few days. It also calls attention to the engines that are on the hospital track waiting to get into the shops.

Altogether this is a very valuable report for the officials of the Operating Department as well as those in the Motive Power Department.

ENGINE FAILURES.

All contentions between the various departments of a railway must be avoided in order to accomplish the best results; provide the most efficient service. Frequently there may be occasions for disagreement between the Operating and Mechanical Departments unless there is a clear understanding as to the responsibilities of each.

Thus, in case of delays to trains, as to what constitutes "engine failures." These should be clearly understood by all concerned. For this purpose the definitions given in this volume (M. P. Form 15, Appendix) were prepared. When points of difference between these two departments are settled in this or some similar manner, neither the Master Mechanic nor the Division Superintendent can quibble over the responsibility for particular delays.

In order that the Operating and Mechanical officials may be fully informed as to engine failures that occur on the different divisions, it is necessary that a daily report of such failures be made by the Train Dispatcher (Form M. P. 16.). Copies thereof should be sent to the Division Superintendent, the Master Mechanic, Superintendent of Motive Power, and other officials interested.

It will be noted by referring to this report that the length of time the train is delayed, cause of delay, and the engine and train numbers are given, all of which are essential.

Unless the Master Mechanic has placed before him every day a statement of the engine failures that occurred on his division during the preceding twenty-four hours, and the cause of same, he has not at hand the information necessary to prevent similar delays in the future, as it is only by possession of full and complete information in each case that the Mechanical Department can avoid the conditions that cause delays. It is therefore the duty of the Master Mechanic every day to study this report, and carefully investigate each case. If, after he has made proper investigation, he thinks there is an inherent weakness in the engine that caused the failure, he should make such recommendations to the Superintendent of Motive Power as the

circumstances demand, not only in regard to that particular locomotive, but all engines of the same class, so as to prevent future failures of like character.

The preceding account of engine failures presents the case from the standpoint of the Operating Department. In order to know the technical causes of delays, it is obviously necessary that the Master Mechanic should also receive a report from the locomotive engineer; furthermore, in cases of dispute as to the causes of delays, the engineer's report gives the Mechanical Department's version of the delay. Form M. P. 17 is intended to provide for this. Sometimes the train dispatcher may not get all the needed information, and so by comparing his report with the one furnished by the engineer, it is made more certain to get at the facts in the matter than if a report was furnished by one only.

The engineer's report is very useful, as it not only gives the time that the engineer was late in leaving with his train, but also the time he was late arriving, and all the delays that he encountered during the trip. It gives the Operating, as well as the Mechanical Department a chance to see how much time was made up, if any, and if delayed by any defect of the locomotive, the Master Mechanic should endeavor to remove such defect. If delayed by block signals, train orders, passing trains, hot boxes on cars, or anything of that nature incidental to the operation of railways, it will be shown on this report.

This has a tendencey to keep everybody keyed up and prevent delays. The engineer does not like to put anything down on this report that will injure his record, and, as the men in charge of the block stations, etc., understand that the engineer is required to make out this report, it keeps them alive to the necessity of doing everything they can to get trains over the road prompt-

ly. So this report is not only good for the information it gives to the Operating and Mechanical Department officials, but it creates an incentive in the minds of all employes who have to do with the progress of trains to see to it that nothing occurs that will in any way reflect upon their services.

At stated intervals—say, every ten days—the Master Mechanic should send the Superintendent of Motive Power and Machinery a summary of the engine failures on his division during the period specified.* It may often happen that the information given in the Train Dispatcher's report of engine failures is wrong, owing to erroneous information furnished by station agents, conductors and others; not, perhaps, intentionally so, but because everybody is in a hurry at such a moment, and there is not always time to make proper investigation. Therefore, the necessity for Master Mechanics sending in this report, in order that the Superintendent of Motive Power may be able to compare the Train Dispatcher's report with this summary and check off all the delays reported by him which are not in fact caused by engine failures for which the Motive Power Department is responsible.

From the reports of engine failures received from the Train Dispatchers and Master Mechanics, the Superintendent of Motive Power and Machinery compiles a Monthly Record for each division showing the cause of each failure, the date on which it occurred, and the numbers of the locomotives causing the delays.†

This permanent record shows in convenient form the number of engine failures from each cause daily, and a

*M. P. Form 18, Appendix is intended for this purpose.
†M. P. Form 19, Appendix.

summary of each one of these reports gives the totals for the whole month.

From the record of engine failures (Form 19) a summary is made at the close of every month of the failures which occurred during such month, showing the total number on each division occasioned by each of the various causes.* These causes are classified under different headings: hot bearings, machinery failures, boiler failures, air-brake failures, and miscellaneous. There should be blank spaces left under each heading to write in items not printed in the blank.

By means of this report, comparisons may be made with other months, and with the corresponding month of previous years. It shows up at once the most prevalent causes of engine failures, and if they are numerous, it indicates where prompt action should be taken in order to reduce their number.

Much valuable information can be obtained from this report, and when officials have this before them they are in possession of facts and figures that will enable them to take proper steps to eliminate many of the causes of engine failures, and thereby provide a better service.

No well organized Motive Power Department, therefore, it is thought, should be without a report of this character.

KEEPING THE TIME OF LOCOMOTIVE ENGINEERS AND FIREMEN.

One of the most important duties connected with the supervision of locomotives is that connected with keeping the time and ascertaining the wages of engineers and firemen. This also involves incidentally keeping

*M. P. Form 20, Appendix.

account of the particular kind of work they are engaged upon, where the work is performed, the time of its performance, and such other particulars as may be necessary to compute the wages and form statistical data for the use of those interested in the performance of locomotives.

The manner in which this is done and the forms that are used will depend in some minor particulars on the bases for computing wages, whether by the hour, or the number of miles run, or otherwise, as the case may be. This fact, with the attendant circumstances, must therefore be kept in mind in the study of what follows in connection with "keeping the time of locomotive engineers and firemen."

In order to keep the time of the locomotive engineers and firemen accurately, it is necessary to receive from each engineer a written report giving the particulars of all time worked.* He is required to make out this report at the end of each trip, and drop it in a box provided for this purpose in the round-house at his home terminal. The round-house foreman then forwards the trip report to the timekeeper. The timekeeper receives from the Train Dispatcher a daily report of all train movements, with which he compares the engineer's trip report, and if there are any discrepancies the engineer's report is sent to the Division Superintendent for investigation, and for his approval or disapproval. In this way a proper check is made of the time claimed by enginemen.

On the reverse side of the engineer's trip report should be written the particulars of all time claimed in excess of the mileage allowed for the trip. For example, in work train service, the number of hours should be given; also a description of the work per-

*M. P. Form 21, Appendix.

formed. The same is true of switching service and delayed time, so that the timekeeper not only shall have the number of hours worked in the various kinds of service, but the hours between which the engineer worked, as well as the description of the work; if for switching, where the switching was done; if for delayed time, where the delay occurred; also the cause of the delay. In this way the timekeeper has the information necessary in order to verify the time.

For use in verifying the time claimed by enginemen, the timekeeper should receive from the Train Dispatcher a daily report of train movements.* This report should give all the particulars regarding each train, such as the train number, locomotive number, names of engineer and conductor, stations between which the train was run, time of departure and arrival, number of hours the men were on duty, etc.

It is a very easy matter, when the engineer's trip report is compared with the Train Dispatcher's report for the timekeeper to notice any differences there may be. When it is necessary to correct the engineer's trip report, the engineer should be notified at once, so as to give him an opportunity to correct his report, or to say why he should or should not be allowed the time claimed.

For reporting the time of engineers and firemen on engines engaged in switching service, a special blank is used.† On some roads a day's work for engineers and firemen engaged in switching service consists of twelve hours; on some, ten hours; and so on.

This form of report provides for the name of the

*M. P. Form 22, Appendix.
†M. P. Form 23, Appendix.

engineer and fireman, the time the day's work was begun, and when ended. It also has a space in which to enter the time taken for meals.

Any work performed outside of the ordinary switching work is entered on the back of this time slip.

This report should be sent to the official directly in charge of the switching for his certification; at outside points he may be the agent or foreman in charge of the switch engine. It may also be compared with the time of the foreman of the switch engine, so the timekeeper may know that the time is correct before same is entered in the book.

The agent, yardmaster, or other official in charge of switching service should make a report to the timekeeper of the time worked by the crews of switching engines, for use in verifying the time claimed by the enginemen and switchmen.*

This report gives the number of engines engaged in switching service at each station each day, together with the names of the enginemen and trainmen, and the time they commenced and quit work; also any time that should be deducted. This report takes but a few minutes each day to fill out, and it is very important in verifying the time of switching crews.

As soon after the close of each month as possible, the locomotive engineer is required to make a report of all time worked during the month and forward same to the timekeeper.† In the proper columns should be entered the number of the engine he was employed on each date, also the name of the fireman with him, the number of hours claimed, and the kind of service he was engaged in.

*M. P. Form 24, Appendix.
†M. F. Form 25, Appendix.

When this report is received by the timekeeper he compares it with the time he has credited to the engineer and fireman on the time book, and if he has made any omissions his attention is then called to same; if the engineer has claimed something that he has no time slip for, he should make due investigation, so as to have the allowances to the engineers and firemen all in before the books are closed. This precludes engineers claiming after pay-day that their time is not correct, for their time will have been compared with the engineers' time-slip, and every irregularity corrected before the pay-rolls are made out.

A time book is provided for keeping the time of engineers and firemen made up of loose leaves which are bound together when the work is completed, in the office where the time is kept. Thus the names of the employes are easily kept in alphabetical order (or otherwise, as desired), and new leaves may be inserted whenever needed.

Similar forms are used for keeping the time of both engineers and firemen, the positions of these titles being reversed in each case.*

In the column headed "Miscellaneous Time," is entered all time dispatching, trying engines, acting as witness in law cases, or other time not in actual service on road or switching work.

In column headed "Switching Time," is entered the time in which a crew is engaged in yard switching.

In column headed "Running Time," is entered total number of hours allowed each day for such service. When pay is based on the number of miles run, the total miles divided by ten will represent the hours, the term hour representing ten miles. The actual hours for which compensation is allowed is entered in

*M. P. Form 26, Appendix.

these columns, according to the class of engine in service.

In the column headed "Engine Number," is entered the number of the engine as shown on the engineer's trip report. In case an engine crew has more than one engine on a given date, the number of miles for each engine should be shown. If this cannot be entered in the proper column, it should be given in the "Remarks" column.

In the columns headed "From" and "To," should be shown the names of the stations between which the service has been rendered.

In the columns headed "Miles Run," is entered the actual number of miles of each kind of service rendered on each divison. All passenger and freight mileage shown should be the actual number of miles between the stations named, as indicated by the time tables.

The mileage for "Work" service should be computed at eight miles per hour when compensation is made on the basis of hours worked, and the mileage does not exceed this amount. If the actual miles run exceed eight miles per hour, they should be shown.

Switching mileage and pusher service should be computed at six miles per hour. Light mileage,* which is also shown in switching column, is actual mileage as shown by the time table.

The location and kind of service entered in the "Work" column should be fully explained in the "Remarks" column, as all service of this nature must be charged to the account benefited thereby.

In the columns headed "Delayed Time" and "Overtime" should be entered amounts, which added to one-tenth of the miles run will equal the hours allowed for a run in which delayed or overtime occurred.

In the column headed "Constructive Mileage"

*Light mileage or a light engine is where an engine and tender passes over the road without any cars attached whatever.

should be entered the excess of the time allowed over the actual time worked, when under the terms of compensation the enginemen are entitled to pay for less than a full day's work. For example, a freight crew on a certain date, makes a trip of 80 miles in less than eight hours, which is all the work they are called upon to do, and which is equivalent to eight hours' work, but as they are entitled to ten hours or a full day's pay, 20 miles is entered in the "Constructive Mileage" column, which added to the 80 miles actually run, equals 100 miles or ten hours' work.

At the close of the month each sheet should be footed and proved by comparing the total footings of the hours with those of the mileage.

The total footings of the hours at each separate rate should be shown in the column headed "Number of Hours Allowed," and the amount of wages at each separate rate computed and entered in the column headed "Amount." These amounts should be footed and the total entered on the pay roll.

The foregoing formulas represent particular methods for determining wages, and will require to be changed in minor particulars it is probable to meet different methods, as has already been pointed out.

THE ENGINEHOUSE REGISTER.

A record book should be kept in each roundhouse, in which the engineer should be required to register his name and the time of his departure (or arrival); also such other particulars regarding his trip as may be required, as, for example, the train number, engine number, kind of train, destination, name of fireman, etc.* The same book may be used for both departures and arrivals, one page being headed "Departures" and the opposite page "Arrivals."

*M. P. Form 27, Appendix.

A column may also be provided on the record of "Arrivals" for the engineer to insert the number of hours he and his fireman were on duty since the commencement of the trip. Thus the roundhouse foreman will not call on them to go out again until the time allowed them for rest under the rules has elapsed.

The Enginehouse Register is also a valuable record for the use of the timekeeper in settling questions which may arise regarding the time of arrival or departure of engines and crews, in checking the engineer's trip reports.

DELAYED TIME AND OVERTIME ALLOWED ENGINEERS AND FIREMEN.

As soon as possible after the close of each month a detailed statement of the delayed time and overtime allowed engineers and firemen should be forwarded to the Superintendent of Motive Power and Machinery by the timekeeper.* The information required in its compilation is obtained from the time book (form 26), and, like that form, this report is arranged to meet a particular method of computing the wages of enginemen. It is of value because it shows the causes of the overtime or delayed time, and thus enables the officials in charge to take proper measures to curtail unnecessary allowances of this nature.

From the foregoing detailed return (form 28) a summary showing the cost of all time of this nature allowed engineers and firemen on each division is compiled in the office of the Superintendent of Motive Power and Machinery, copies of which should be sent to the Division Superintendents, general officers of the Oper-

*M. P. Form 28, Appendix.

ating Department, and others interested.* Upon receipt of this the Operating Department officials can thoroughly investigate the causes for claims of this nature, and take such steps as they think necessary in order to reduce the amounts allowed for this class of time.

LOCOMOTIVE MILEAGE.

For use in the compilation of the "Locomotive Report" (Form 45), and for other purposes, it is necessary to obtain the total mileage made by each engine in each class of service, as well as the total mileage made by all engines on each division. A statement of this character should be made each month by the timekeeper.† The mileage made by each engineer with each engine, as shown by the time book (form 26), is entered on this statement under the proper engine number and in the column corresponding to the class of service in which the engine was engaged.

After the mileage made by each engineer has been entered in the proper places on the foregoing statement (form 30), the mileage made by each engine should be summed up, and the totals thereof for each division recapitulated. A copy of this recapitulation (M. P. Form 31, Appendix) should be sent to the General Storekeeper or other official in charge of these accounts by each timekeeper, showing the total mileage made by each engine in the different classes of service on each division, and the total locomotive mileage on the division for the month named.

In the General Storekeeper's office, or elsewhere, a record is kept of the mileage made by each engine on all

*M. P. Form 29, Appendix.
†M. P. Form 30, Appendix

divisions.* This record is compiled from the reports of the locomotive mileage made on each division (form 31) received from the local timekeepers, and shows the mileage made by each engine, monthly (and also for the year), in the different classes of service. It forms the basis of statistical statements, comparisons, etc.

For the purpose of ascertaining at any time the mileage made by an individual engine, either in the aggregate or in each class of service separately, this record will be found to be of great service. It is often necessary to know the mileage made by a certain engine on a particular division during a certain month, or for several months, and by referring to this record the information may be obtained at once. It is also useful in determining whether the wheels under each locomotive make the mileage which is guaranteed by the manufacturers.

COST OF REPAIRS OF LOCOMOTIVES.

In order to compute the total cost of the repairs made to each locomotive, the General Storekeeper or other official should receive a report (M. P. Form 33, Appendix) every month from the local storekeepers at the various shops showing the expenditures (for material and labor separately) on account of each locomotive.

Upon receipt of the foregoing reports of the expenditures at each shop for repairs of locomotives, the General Storekeeper should enter the amounts charged to each locomotive by the various storekeepers on the "Monthly record of repairs on each locomotive" (M. P. Form 34, Appendix). From this record the total amount charged on all divisions for material and labor expended on each engine is ascertained.

*M. P. Form 32, Appendix.

LOCOMOTIVE MILEAGE AND REPAIRS.

Each month the General Storekeeper or other official should send to the Superintendent of Motive Power and Machinery a report showing the kind of service each engine was engaged in; the number of miles run in each kind of service; and the cost of repairs—general, heavy and light.*

From this report the Superintendent of Motive Power can determine whether the cost is excessive or not; particularly is this true in regard to material. If the charge for material on a certain engine seems to be too high, he should ask the storekeeper for a statement of the material furnished for use on that engine. Perhaps new flues and tires account for the unusual amount, but if, after taking them into account, the cost still seems to be excessive, the accounts should be carefully verified.

This report also enables the Superintendent of Motive Power to compare the cost of locomotive repairs and the mileage made on the different divisions each month.

Each Master Mechanic should be informed every month of the mileage and cost of maintenance of the locomotives on his division. Such a report should be compiled for each division by the General Storekeeper or other official from his records of the individual locomotives, and this report should be sent to the Master Mechanics as soon as the information required in its compilation can be obtained.†

Then if the Master Mechanic should find that certain engines are costing much more for repairs than others in the same service, he should investigate the matter and take steps to eliminate all unnecessary items of expense.

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*M. P. Form 35, Appendix.
†M. P. Form 36, Appendix.

A record book should be kept in the office of the General Storekeeper or other official, from which he may obtain, at any time, the mileage made by each engine in the different classes of service, during any month of the year on a particular division; also the cost of material and labor expended in repairing such engine.*

When an engine passes through the shops for heavy or general repairs, the charges on account of same should be apportioned to each division (if more than one), on which such engine has made mileage since it has last received heavy or general repairs. This record is of value in obtaining the mileage made by engines in order to apportion the cost of repairs in the manner mentioned.

FUEL USED ON LOCOMOTIVES.

For purposes of accounting for coal delivered to locomotives, the engineer is required to give the person in charge of the coaling station a ticket (of the form provided) for each ton of coal received.†

The tickets are in book form and perforated so that any number may be removed at one time. They are numbered consecutively, the first being numbered 0, the next 1, and so on. Thus the number of the first unused ticket will represent the number of tons delivered to the engineer during the month.

A new book is given to each engineer at the beginning of the month. His name should be written on the cover, and his number and the name of the division to which he is assigned, stamped on each ticket. At the end of the month the book is returned to the Master Mechanic, with all unused tickets therein; he is thereby enabled to ascertain the quantity of coal used by each

*M. P. Form 37, Appendix.
†M. P. Form 38, Appendix.

engineer during the month. The information thus obtained is used in determining the relative economy practiced by the different engineers in the use of fuel each month. (See M. P. Form 85, Appendix.)

To aid in determining the quantity of coal used in the different classes of service, it will be found advantageous to have the tickets printed on different colored paper, as say red for passenger service; white for freight, and blue for work trains and switching service.

Each month a detailed report should be made of the fuel delivered to locomotives at each coaling station, showing the quantity delivered each day, the kind of service in which the locomotive was engaged, etc. (See M. P. Form 39, Appendix.) Such reports should be made by the agent or other person in charge of the accounts of the coaling station, and sent, with the tickets received from the engineers, to the storekeeper designated to audit same.

Before forwarding the report, it should be compared with the one for the previous month, and any discrepancies carefully investigated.

Upon receipt of the reports and tickets from each coaling station on the division, the storekeeper should verify the reports and make a summary thereof showing the total quantity of fuel delivered to locomotives in each class of service at each station during the month named. A copy of this summary (M. P. Form 40, Appendix) should be forwarded to the General Storekeeper or official designated to receive same, who is thereby enabled to determine the total quantity of fuel delivered to locomotives on all divisions of the road.

Reports and methods generally similar to the preceding may be used to advantage when oil or other combustible is used for fuel.

OIL AND WASTE USED ON LOCOMOTIVES.

For purposes of accounting for oil and waste used on locomotives, the engineer is required to give the storekeeper tickets representing the quantity of oil and waste received whenever he obtains supplies of this nature from the storehouse.*

Like the coal tickets, these are also in book form and perforated so that any number may be removed at one time. They are also numbered in consecutive order, the first being numbered 0, the next 1, and so on.

A new book is given to each engineer at the beginning of each month, with his name written on the cover, and his number and the name of the division to which he is assigned, stamped on each ticket.

At the end of the month the book is to be returned to the Master Mechanic with all unused tickets therein. The number shown on the first unused ticket, mulitiplied by the quantity designated on the ticket, represents the quantity of each kind of oil or waste delivered to each engineer during the month.

To aid in determining the quantities of the different kinds of oil and waste used, it will be found advantageous to have tickets printed on different colored paper, as blue for engine oil, red for valve oil, green for signal oil, white for car oil, yellow for cotton waste and brown for wool waste.

From the tickets received for oil and waste delivered to locomotive engineers, a report should be made by the disbursing storekeeper and sent to the General Storekeeper, or other official, showing the number of pints of oil and pounds of waste disbursed during the month.†

From these reports the recipient ascertains the total number of pints of oil and pounds of waste delivered to

*M. P. Form 41, Appendix.
†M. P Form 42, Appendix.

locomotives on each of the different divisions of the road. This data is used in compiling the cost of oil and waste as shown in the "Locomotive Report" (Form 45.)

REPORT OF ENGINES WIPED DAILY.

In order to make proper distribution of the time of locomotive wipers and dispatchers and roundhouse laborers, for the different classes of service in which the engines are engaged, it is necessary that the roundhouse foremen should furnish a report each month showing the number of engines wiped each day. For this purpose the form illustrated elsewhere in this volume is designed. (See M. P. Form 43, Appendix.)

LOCOMOTIVE STATISTICS.

Exhibits of the results of the operations of a railroad from month to month or year to year are of the greatest value to the officials in charge of the various departments. Of especial interest are those returns which recount the performance of locomotives; the work done and the cost thereof for the various items of expense connected with the locomotive service, such as fuel, oil and waste, wages of engine and roundhouse men, cost of tools and supplies, and the expense of maintenance (both for material and labor).

The value of such a report may be greatly augmented by so compiling the statistics as to show the results of the operations of different parts of the road separately. The arrangement should also be such that the results for the particular period for which the report is compiled may be readily compared with the corresponding period of the preceding year, or otherwise, as desired.

In addition to the statement of gross results, the locomotive report should also show the cost per unit of service (in the case of locomotives this is the gross ton-

mileage of the trains hauled, including the weight of cars and contents), for passenger and freight service separately.

From a statement of this nature, the relative efficiency evinced in the operation of the various divisions of the road, and of the same division at different times, may be approximately determined. Thus the officials of the Operating Department are informed as to the gross tonnage moved per mile run by passenger locomotives and by freight locomotives, and are thus enabled to see that the power is utilized to the fullest extent possible. And the Motive Power Department officials being advised as to the cost, in detail, of performing the service, are enabled to investigate all seeming irregularities, and check extravagances.

The locomotive report illustrated in this volume (M. P. Form 45, Appendix), in addition to the various statistics enumerated in the foregoing paragraphs, also shows other facts—both for the road as a whole, and for parts thereof—of great importance, such as the number of miles of road operated, the average number of locomotives in service, the total quantity of fuel consumed, the mileage made by locomotives in each class of service, and the average mileage per locomotive, also the mileage of passenger and freight cars, etc.

For use in comparing the total cost of fuel during the periods included in the statement, the prices used in computing the cost are also given, thus indicating whether the gain or loss represented by the total charge is due to difference in the price, or the economical or extravagant use of fuel.

A careful study of the form of report herein given will amply repay the student; the form, of course, may be changed to meet special needs or requirements.

The detailed information required in compiling the locomotive report described is obtained from the

various storekeepers or other persons in charge of the accounts at the different shops where the expense is incurred. For this purpose the "Monthly summary of charges to various operating accounts for material and labor account of engines on each division" (M. P. Form 44, Appendix) is provided.

KEEPING TRACK OF THE WHEELS UNDER LOCOMOTIVES AND TENDERS.

As both safety and economy of operation hinge largely on efficiency or otherwise of engine and tender wheels, careful provision is required to be made in order that supervision of the same may be prompt and full. This requires many different returns and records.

The manufacturers of cast iron wheels for engine trucks and tenders usually furnish them under a contract or agreement which provides that if any of the wheels prove defective and must therefore be removed before they have run a specified number of miles, the manufacturers will refund to the railway company an amount representing such deficiency.

For this reason it is necessary that a record be kept of the service of each wheel placed under locomotives. To facilitate this, serial numbers are stamped or cast on all wheels. When a wheel of a given number is applied to a certain engine, and when such wheel is removed for any cause, both dates and the cause of removal are duly recorded opposite the number of the wheel. The mileage made by the locomotive between these two dates represents the number of miles run by such wheel. The cause of the removal is always given, as there are certain defects which are not chargeable to the manufacturer, as, for instance, flat spots caused by sliding, due to the improper application of the brakes on the part of the railway employes, etc.

At the close of the month the foreman at each shop or roundhouse where wheels are applied to or removed from locomotives is required to send a report (M. P. Form 46, Appendix) to the Division Master Mechanic showing the particulars of all cast iron engine, truck and tender wheels applied and removed during the month.

These reports from each shop are then consolidated by the Master Mechanic into one report for the division, a copy of which is sent to the Superintendent of Motive Power and Machinery for his use in ascertaining the service of each wheel.

Upon receipt of the reports from each division, the Superintendent of Motive Power and Machinery compiles a statement of all wheels removed from locomotives during the month, showing such facts regarding same as may be necessary, as, for instance, the shop where removed, number of the engine from which removed, the date applied, date removed, mileage made in the interim, the date each wheel was cast, and finally the cause of removal. (See M. P. Form 47, Appendix.)

Separate statements of this character are made for the wheels received from each manufacturer, and also for each size and kind of wheels. These reports show what wheels, if any, have failed to make the mileage guaranteed by the makers, and afford valuable information in other directions.

From the foregoing detailed statements of wheels removed (Form 47), a synopsis is made for the use of the Superintendent of Motive Power, showing the number of wheels removed during the month on account of sliding, on account of sharp flanges, for other causes, and the total number removed for all causes; also the average mileage made by the wheels removed for each cause and for all causes.* If an undue proportion of

*M. P. Form 48, Appendix

the wheels are removed on account of sliding, it would appear that the air brake apparatus is not being properly maintained, or that those in charge are careless in the application of the brakes. Or if an excessive number of wheels are removed on account of sharp flanges, this may be due to the mismating of wheels; or it may be caused by the truck not being properly squared up. Thus, upon investigation the cause of the trouble may be readily determined, and the proper remedy applied.

The Superintendent of Motive Power sends to the Purchasing Agent a statement showing the total number of each manufacturer's wheels removed each month, the average mileage made, the number of wheels removed which failed to meet the guarantee of the makers, and such other particulars as may be necessary. (See M. P. Form 49, Appendix.) This information is also valuable in enabling the Purchasing Agent to determine what make of wheels is giving the best general results and averaging the largest number of miles.

Each month the Superintendent of Motive Power should prepare a statement of wheels removed which have failed to make the mileage guaranteed by the makers, and which have also been accepted by the wheel company's inspector, to be returned for credit.*

It is suggested that claims for credit for all failed wheels should be made as follows: Bills should be rendered against the manufacturers of the wheels for the difference between the guaranteed and the actual service. From the cost of the new wheel is deducted the value of same as scrap, which is computed on the basis of the value per gross ton. The difference represents the net value or cost of the wheel for the guar-

*M. P. Form 50, Appendix.

anteed mileage. Therefore, the amount to be refunded by the manufacturer is the same proportion of this net value or cost as the mileage deficiency is of the guaranteed mileage. To this amount should be added the allowance, covering the cost of labor for removing and replacing each wheel failing to make its guarantee.

The following example will illustrate the method of computation. A wheel guaranteed to run 70,000 miles runs only 40,000 miles when it is necessary to remove it on account of some defect, leaving a deficiency of 30,000 miles.

Value of new wheel	$8.00
Value of wheel as scrap	4.50
Net value	$3.50

$3.50 divided by 70,000 miles equals five cents per thousand miles. The deficiency of 30,000 miles at the rate of five cents per thousand miles equals $1.50, the amount allowed account of deficiency. To this amount is added the charge for the labor of changing the wheels, the sum being the amount of the bill against the maker.

A record book should be kept in the office of the Superintendent of Motive Power and Machinery, in which the numbers of all cast iron wheels received should be entered in consecutive order. The entry in each case should also give the size, kind, and name of the manufacturer, as see the illustration of the form (M. P. Form 51, Appendix).

When a wheel of a given number is reported applied to a certain locomotive, the place, date, number of the axle, and number of the engine are entered in the proper columns opposite the number of the wheel. Then when the wheel is reported removed, the date and cause of removal are noted in the spaces provided. The history of each wheel is thus readily referred to, and from

this record the information required in computing the mileage made by each wheel is easily obtained.

STEEL TIRED ENGINE TRUCK AND TENDER WHEELS.

Reports and records somewhat similar to those used in connection with cast iron wheels are also required in keeping track of the steel tired wheels under locomotives. Although these latter may not be guaranteed by the makers for a specified period or number of miles, yet it is desirable that adequate records be kept in order to see what manufacturer's tires are giving the best service.

For this reason the various shop foremen report to the Master Mechanics the particulars of all steel tired engine truck and tender wheels applied to or removed from locomotives each month, and these reports are summarized by the Master Mechanics, a copy of the summary for each division being sent to the Superintendent of Motive Power and Machinery.*

In the office of the Superintendent of Motive Power and Machinery a record book is kept, in which the numbers of all steel tires for engine truck and tender wheels are entered consecutively. When wheels are applied to a locomotive, the number of the engine, and the place and date applied are entered in the columns provided opposite the number corresponding to the tire. When removed the place and date of removal are also entered, and the mileage between the two dates computed and entered in the column provided. Several sets of these columns are provided opposite each tire, for the reason that the tires after being removed from one locomotive are "turned up" and applied to another, until worn too thin to permit of this being done with safety. The

*M. P. Form 52, Appendix.

form of record illustrated in this volume (M. P. Form 54, Appendix) is admirably fitted for this purpose.

In order that the Superintendent of Motive Power and Machinery may find at any time the numbers and records of the truck and tender wheels under any locomotive, an index is provided, two pages (opposite each other) being used for each locomotive. (M. P. Form 53, Appendix.) On these pages are entered the numbers, sizes and kinds of the wheels and tires under that engine, also the names of the manufacturers, and dates applied and removed. The left hand page may be used for cast iron wheels, and the right hand page for the steel tires and wheel centers. Thus when it is desired to refer to the detailed history of any wheel or tire under a particular locomotive its number may be readily obtained from this book, and the record then found opposite the number of the wheel or tire in the record books provided for same. (Forms 51 and 54, Appendix.) In this way if a certain engine has broken a tire, this index book will designate the maker and number of the tire, and by turning to the record book (Form 54, Appendix), the history of the tire is easily found.

DRIVING WHEEL TIRES.

Separate records are kept by the Superintendent of Motive Power and Machinery for all driving wheel tires. In all cases when such tires are applied to or removed from locomotives, or turned, the shop foreman is required to make a report thereof, stating the numbers of the tires, name of manufacturer, diameter of wheels, engine number, date applied, removed or turned, thickness of the tire, and cause of removal (M. P. Form 55, Appendix).

In the office of the Superintendent of Motive Power and Machinery a record book is kept, in which the numbers of all driving wheel tires are entered in numerical order; also the name of the maker, the inside diameter of the tire, and thickness of the tire when new (M. P. Form 57, Appendix). When the tire is reported applied to a locomotive, the number of the engine, and place and date applied are entered opposite the number of the tire. When reported removed, the place and date are entered in the columns provided; also the thickness of the tire after turning. The mileage made by the locomotive from the time the tire was applied until it was removed is then computed and entered in the record book opposite the number of the tire. As tires may be applied to several different locomotives before being worn out and scrapped, a number of columns are provided, so that a record may be kept of the particulars in each case.

From this record the Superintendent of Motive Power is enabled to determine the total mileage made by each tire, as well as the number of miles made between each turning. Thus comparisons may be made between the tires of different manufacture.

To assist in looking up the history of the driving wheel tires under any particular locomotive, an index is provided, a separate page being used for each locomotive (M. P. Form 56, Appendix). On the page representing each engine, is listed the numbers of the tires under that locomotive; also the name of the maker and date applied. When removed that date is also entered in the proper column. The numbers of the tires being given in this index, the detailed history of each one is readily found by turning to that number in the record of driving wheel tires (Form 57).

SHOP LABOR.

Effective supervision of the pay rolls for shop labor in the Motive Power Department is necessary in the light of both economy and effective operation. Returns and records must therefore be such as to secure this. With this in mind the following is suggested:

As soon as possible after the close of the month every Master Mechanic should prepare a statement of the pay rolls for each sub-shop, comparing the rolls for the current month with those of the previous month of the same year and the corresponding month of the preceding year.* All increases and decreases should be explained in detail, so that the Superintendent of Motive Power and Machinery can see how much is due to changes in rates of pay, differences in number of hours worked, or increase or decrease in the force employed.

The Superintendent of Motive Power, by means of the information contained in these reports and his reports showing the condition of power on the various divisions, will be enabled to determine whether it is advisable to increase or decrease the pay rolls on the several divisions in order to maintain the power at the required standard.

In the office of the Superintendent of Motive Power and Machinery a summary of the several Master Mechanics' reports should be made, showing the total amount of the pay rolls at each point, and a copy of same forwarded to the officers of the Operating Department.

All shop foremen should send to their Master Mechanics a report showing the number of men employed at such shops on the last day of every month, or oftener, if required. This report should show for each kind of

*M. P. Form 59, Appendix.

work separately: the number employed, the rates per hour, day, or month, and the total and average amounts paid for each class of labor.*

This report will enable the Master Mechanic, by comparing the number of engines that were handled each day at the respective shops on his division, to determine the relative force of the departments and whether they should be reduced.

Each Master Mechanic should make a summary of the reports (Form 60) received from the different shops, showing in one statement the same statistics regarding the forces at each of the shops on his division. A copy of this summary (M. P. Form 61, Appendix) should be sent to the Superintendent of Motive Power and Machinery, who, by comparing the number of men employed and the amount of the pay roll at the different shops, with the output of such shops for each month, is enabled to determine (also taking into consideration the number of engines he has waiting to go into the shop), whether the pay rolls on a certain division are excessive or otherwise.

For the information of the officers in charge of the Motive Power and Operating Departments, the Superintendent of Motive Power and Machinery should have prepared a detailed statement of the force employed at the principal shop (and for others if thought desirable), in form generally similar to the two foregoing reports (see M. P. Form 62, Appendix). In addition this report should also show a summary by divisions of all the other shop pay rolls; also a recapitulation of the total shop forces employed on each division. Thus the officers in charge are kept informed as to the expenditures for labor in the Motive Power Department,

*M. P. Form 60, Appendix.

and in the event of an increase in the total pay roll, the point where it occurs is known, and such investigation instituted as the facts warrant.

BREAKAGES OF LOCOMOTIVE PARTS.

In order that the Superintendent of Motive Power and Machinery may avail himself of the lessons to be learned from the failures and breakages of the different parts of the mechanism of locomotives, detailed reports and sketches are required from the inspectors and foremen, showing in each case, the nature of the fracture, the probable cause, and such other particulars as may be necessary. Since many of the men required to render these reports may not be sufficiently skilled in drawing to make such sketches as are necessary for an intelligent understanding of the case, and also to secure uniformity in the returns, blank forms are provided with outline drawings of certain parts of the locomotive. Then all that is necessary on the part of the foreman or inspector is to indicate the location and shape of the fracture on the illustration of that part, also noting the dimensions to certain fixed points, in addition to the written explanation of the breakage. (See M. P. Forms 63 to 77, inclusive, Appendix.)

These reports should be forwarded by the maker to the Master Mechanic, who makes such notations thereon as he thinks necessary, before forwarding them to the Superintendent of Motive Power and Machinery. After being examined by the Superintendent of Motive Power, with the view of ascertaining what parts were broken through the carelessness of employes, these reports should be forwarded to the Mechanical Engineer or other person in charge of the designing of the locomotives and locomotive parts, who will determine whether the breakages were caused by defects in construction, or through natural wear. The information

so obtained will enable him to take such steps as may be necessary in order to avoid similar breakages from the same causes in the future.

For example, if certain classes of engines are breaking certain parts of the mechanism, it will be shown by these reports wherein the broken parts are defective, and the Mechanical Engineer, together with the Superintendent of Motive Power, can then make such provision, by either strengthening the parts or changing the construction of same, as will eliminate, or at least materially reduce, the number of failures or breakages.

INSPECTING AND REPAIRING LOCOMOTIVE AND STATIONARY BOILERS.

One of the most important duties in connection with the Motive Power Department is the effective supervision of locomotive and stationary boilers. Whenever repairs are made to boilers, detailed reports of the work done are required, so that all changes can be properly recorded. Frequent inspections should be made, and the facts as found duly recorded, together with the name of the inspector, so that, should occasion require, the responsibility in any case may be readily determined.

Whenever a boiler has been repaired, a report showing in detail the condition of such boiler, and the nature and location of the repairs, should be made by the foreman, and sent to the Master Mechanic, who, after examining same and making any notations in regard to it which he thinks necessary, should forward it to the Superintendent of Motive Power and Machinery. (See M. P. Form 78, Appendix.) On the blank is printed a diagram of the boiler, on which the foreman should indicate the location and extent of all repairs. Both old and new patches should be shown—different colors of ink being used to indicate whether new or old.

It is very essential that stationary and locomotive fire-box stay-bolts should be inspected periodically; for locomotives, say once a month, and for stationary boilers, once every ninety days. All stay-bolts that are not drilled with "tell-tale" holes should be inspected by a competent boilermaker, who uses a hammer for this purpose, determining by the sound whether broken or not. Where "tell-tale" holes are drilled, they do as their name implies, tell the tale automatically when broken, by showing through the drilled hole a leakage of steam or water. These holes should be drilled to a depth extending about a quarter of an inch beyond the inside of the plate, when the bolt is in place.

A record book (M. P. Form 79, Appendix) should be kept at each shop, in which the inspector is required to note the number and location of all broken stay-bolts found by him. The date and number of the engine should also be given, and his signature should be entered opposite the item. When the defective stay-bolts are replaced, the certificate to that effect should be signed by the person making the repairs, and the date noted opposite the inspector's entry.

In order that the Master Mechanic and Superintendent of Motive Power and Machinery may be advised that stay-bolts in boilers are inspected, a report (M. P. Form 80, Appendix) should be sent to the Master Mechanic by each inspector, and a copy sent by the Master Mechanic to the Superintendent of Motive Power, showing the details of all inspections made during the month, as shown by the record book (Form 79).

The usual report of the breakages of stay-bolts (Form 76) should accompany the report so that the Mechanical Engineer can see where these bolts most frequently break, and so take such steps as may be necessary to reduce the number of breakages of this nature.

Usually the Superintendent of Motive Power and Machinery has charge of the stationary boilers. In order that he may know that they are inspected at regular intervals, reports are required from the inspectors, showing the condition of all boilers on the system. Unless there are certain times for inspection, some boilers on a large system are likely to be neglected, and it is only by doing the work systematically and at stated periods that the Motive Power Department officials can be assured that the work is done.

The method of inspection is described in detail on the blank. (See M. P. Form 81, Appendix.)

Intimately connected with the supervision of boilers is the inspection of pressure gauges and safety valves. The men selected to do such work should be men of good judgment and worthy of the great trust.

All steam and air gauges and safety valves should be inspected at least four times a year, and a detailed report thereof should be made to the Superintendent of Motive Power and Machinery, showing their condition; how they were found, and what repairs were made; the report should also show that they have been put in first class condition at least once a quarter.* Such information assures the Motive Power Department that these very important parts of the locomotive have received careful attention, and that there is no excessive pressure carried in the boiler.

In order that the Motive Power Department officials may have a complete record of the details of stationary boilers, and thus know their condition and the pressure carried, a report is required from the shop foreman in all cases when any change is made in a stationary boiler, showing the nature of all work done and the

*M. P. Form 82, Appendix.

exact condition of the boiler when ready to be put in service again. (See M. P. Form 83, Appendix.) Perhaps the condition of the boiler, as shown by the last report, may have been such as to make it necessary to reduce the pressure in the boiler, and not allow the maximum pressure to be carried until certain changes or repairs are made. When these changes are made, a report thereof should be sent to headquarters, so that if the changes made are satisfactory the local officials may be instructed to carry such pressure as is considered safe. Only by such means can a large number of boilers be kept in good order, and the officers in charge feel sure that every boiler is absolutely safe for the pressure carried.

LOCOMOTIVE VALVE MOTION.

A means to an end in the operation of locomotives is to see that the valves are adjusted so as to get the maximum results for the least steam consumption at varying points of cut-off. This should practically be the case at all points of cut-off where the engine has to do the major portion of its work. The adjustment of the valve motion is determined in the office of the Superintendent of Motive Power and Machinery, after a thorough investigation has been made by the use of indicators on each class of locomotives. Ideal indicator-cards for each class of engines should be made and kept in the office of the Mechanical Engineer and Master Mechanic. The card showing the adjustment of the valve motion of a given engine should be compared with the ideal card of the valve motion on that type or class of engine, and the attention of the Superintendent of Motive Power and Machinery and Master Mechanic called to any irregularities in same, so that any necessary adjustments may be made in order to increase the efficiency of the engine.

For purposes of record in the office of the Superintendent of Motive Power and Machinery, a report is required from the shop foremen and Master Mechanics giving in detail the description of the valve motion on all engines passing through the shops. (See M. P. Form 84, Appendix.)

COMPARATIVE RECORDS OF FUEL AND OIL USED BY LOCOMOTIVE ENGINEERS.

There can be no question as to the great need of economy being exercised by locomotive engineers in the use of fuel and lubricants; especially fuel, which constitutes from one-eighth to one-tenth of the total operating expenses of the railroads of this country. As an aid in the accomplishment of this purpose (and to foster a spirit of emulation) monthly statements showing each man's record are prepared and bulletined in all the engine houses on each division. To facilitate comparisons, the engineers in each class of service (passenger, freight, etc.), also those running regularly on similar trains, are grouped together. Such exhibits should show, in the case of fuel, the names of the engineer and fireman, the location of the run, the train and engine numbers, the engineer's mileage for the month, quantity of fuel consumed, average number of miles run per ton or average quantity of fuel consumed per mile run; also the total work performed during the month (expressed in "ton-miles"), and the average quantity of fuel consumed per 100 ton-miles.*

Another purpose of this report is to permit the management to ascertain what relation the fuel consumption from month to month bears to the tonnage of traffic hauled.

*M. P. Form 85, Appendix.

In the enforcement of economy and responsibility a form of statement is used for comparing the records of engineers using lubricating oils, generally similar to that used in the case of fuel. The total number of pints of each kind of oil used by each engineer during the month is shown; also the average number of miles run to the pint. In addition, the cost of the oil used is stated, and the average cost per 100 engine miles.

It may occur that enginemen, thinking cylinder oil a better lubricant than the other lubricating oils, will use it in the driving boxes. In the winter time this will cause trouble by not feeding through the waste. The report (M. P. Form 86, Appendix) will show if there is an excess of cylinder oil used; and as cylinder oil is much more expensive than the other lubricating oils, it is highly desirable that the Motive Power Department should see that it is not used extravagantly—not only on account of its cost, but also because of the trouble it will create if used outside of the valves.

CONDITION OF SHOP TOOLS AND MACHINERY.

To prevent waste and promote efficiency of service, an inventory of the tools and machines in the various shops on each division should be made by the Master Mechanic yearly or oftener. A copy thereof should be sent to the Superintendent of Motive Power and Machinery. The inventory should specify the kind of machines, and give a brief description of same; also the name of the manufacturer, the maker's number, the location, name of the sub-shop, date placed in service, their cost when new, estimated value at the time of making the report, and such notations as to their present condition, etc., as may be necessary for the Superintendent of Motive Power and Machinery to understand clearly the situation at each point.*

*M. P. Form 87, Appendix.

These reports will, among other things, enable the Superintendent of Motive Power and Machinery to detect old-fashioned or obsolete tools and determine their relative value, and whether they should be abandoned.

APPLICATIONS FOR EMPLOYMENT.

One of the most important and valuable things an official has to do is to select men; men fitted for present and possible future work. Hence written applications are required from all would be employes, giving the names and addresses of previous employers, and stating the nature of their previous experience, together with such other particulars as will aid in determining the applicant's fitness for the position desired. Inquiries regarding the qualifications of the applicant should be made of all those who are given as references.*

Bearing in mind that the firemen of to-day will be the future locomotive engineers, it is readily seen that care exercised at the beginning will save the Motive Power Department much trouble that might be experienced in the years to come if such employes were not wisely selected.

If, after due investigation, the application is approved, every applicant for employment on locomotives is required to be examined by the company's surgeon, in order to see that he has no physical defects, such as imperfect sight or hearing, which would disqualify him for this service.

MECHANICAL EXAMINATIONS OF FIREMEN.

The preparatory examinations that those who seek to become firemen must pass, and the examinations

*M. P. Form 88 (for enginemen) and 103 (for shopmen), Appendix.

that they must pass afterwards in order that they may become engineers, are not uniform as regards the particulars of the examinations on different roads. It is not probable that such differences are important. They nevertheless exist, both as regards time and matter.

When any one is employed as a locomotive fireman, the foreman or Master Mechanic advises him as to what will be expected of him and the general nature of his duties. Before going to work, however, he is required to pass an examination pertaining to signals, color blindness and other fundamental matters, as see M. P. Form 88. He is then given a book containing certain questions concerning the operation of a locomotive. At the end of the first year he is examined as to his knowledge of the matters referred to in the first series of questions. Having passed a satisfactory examination, he is given a book with the second set of questions. At the end of the second year he is given another examination, and is then given the third year's book. At the end of the third year he is required to pass an examination on all three books.

The first and second years' examinations are usually made by the Master Mechanic and Traveling Engineer. The third year, which is the final examination, the fireman is examined by a board consisting of traveling engineers from all divisions of the road. This is done in order that the men coming before this board will feel that they are away from the influences and prejudices that might exist on their home division, and confident of getting a "square deal."

In this connection it may be said that in the course of his examination the fireman is required to take sectional parts of the mechanism used in connection with the air brakes, injectors, lubricators, air pumps, valve motion, etc., and trace the operation of each from beginning to end. His average for the final examina-

tion, as well as the previous examinations, must not be less than eighty per cent. If he fails he may be given another opportunity at the expiration of six months. Failing a second time he is relieved from duty.

The many particulars and explanations of importance that suggest themselves and that are properly objects of interest to firemen and those who seek to become firemen are too extended for the space that can be given them here. Those interested in such matters, however, will find them considered at length in another volume of the "Science of Railways" series.

ADVERTISING VACANCIES IN LOCOMOTIVE SERVICE.

On most railways the engineers and firemen rank in employment according to the length of time they have been in the service of the company. The best runs, other things being equal, are given to the senior men. For this reason, whenever a vacancy occurs on a division the Master Mechanic is required to have a notice thereof posted on the bulletin boards in all the roundhouses on the division, stating the number of the train, the terminal points of the run, and any other items in regard to same which may be necessary.* This notice should also specify the time by which all applications for the place must be received by the Master Mechanic, and engineers or firemen must make application within that time if they desire the position.

EMPLOYES AUTHORIZED TO OPERATE LOCOMOTIVES.

In order to avoid the accidents which would inevitably happen through the movement of locomotives by employes not qualified to operate them, each employe upon entering the service of the Motive Power Department is advised of the company's regulations

*M. P. Form 89, Appendix.

in this respect, and the penalty for the violation of such rules. The form of notice illustrated elsewhere in this volume states explicitly what employes are authorized to move or operate locomotives, and also provides for the written acknowledgment of its receipt by the employe.*

EMPLOYMENT OF MINORS.

To protect the company from financial loss and for other reasons, the written consent of the parents or legal guardians is required in every instance when young men under age enter the employment of the pany.† Such release is executed in duplicate, one copy being kept in the office of the Division Master Mechanic, the other being sent to the Superintendent of Motive Power and Machinery for filing.

CERTIFICATE OF COMPLETION OF APPRENTICESHIP.

Whenever employes have completed their term of apprenticeship in any trade or line of work in the shops of the Motive Power Department, a certificate reciting the facts is given them.‡ This serves the purpose of a diploma, testifying that the person named therein has mastered his trade, and is entitled to a journeyman's wages.

DELAYS IN HANDLING LOCOMOTIVES AT TERMINALS.

The economical use of locomotives requires that they be handled promptly at terminal points, and upon arrival after one trip be prepared for the next with the minimum loss of time. Especially is this true during

*M. P. Form 90, Appendix.
†For form of release see M. P. Form 91, Appendix.
‡M. P. Form 92, Appendix.

the busy season, but at all times it is necessary to avoid having trains delayed on account of the tardiness of employes in handling locomotives at engine houses.

To aid in supervising effectively this feature of the service, a daily report is required by the Master Mechanic from all roundhouse foremen, showing the length of time each engine is held for various causes, as for coal, water and cleaning fire; for repairs; and for orders; also the total time held for all causes, and the average time held per engine.* Such a report need not be required for engines regularly assigned to particular trains, and not available for other service, as in the case of passenger locomotives.

The Master Mechanic should carefully scrutinize these daily reports, and correct all conditions causing unusual delays. Each week he should send the Superintendent of Motive Power and Machinery a summary of the daily reports, for his division in order that the Superintendent of Motive Power and Machinery may compare the service on one division with that on another, and take such action as he deems advisable in order to improve the service.

LOCOMOTIVE TOOLS AND SUPPLIES.

The practice of care and economy in the use of tools and supplies by enginemen is to be encouraged by every means possible. As in the case of fuel and oil, much good can be accomplished in this direction by the comparison of the records of the different engineers in regard to the cost of the supplies of this nature used by them. With this object in view, on the first of the month each engineer is provided with a book of requisition blanks to be used in all cases in obtaining tools and supplies from the storehouse.† These requisitions

*M. P. Form 93, Appendix.
†M. P. Form 94, Appendix.

are in duplicate, the original being given to the storekeeper, and the copy (made by use of carbon sheets) retained in the book. The requisitions and records are also numbered consecutively, so that the person examining the book can see that no records are missing. At the end of the month the book, with the carbon records and all unused requisitions, is returned to the Master Mechanic, who prepares a statement showing the cost of the tools and supplies issued to each engineer. This statement should be bulletined in all roundhouses on the division. Those who are shown to be extravagant in the use of supplies will thus be induced to correct the fault. In this way much loss from the wasteful use of locomotive tools and supplies will be avoided.

INSPECTION OF LOCOMOTIVES.

At the end of each trip it is necessary to have a locomotive carefully inspected and all needed repairs made before it is put in service again. This work, carefully done, will prevent many accidents and delays which might otherwise occur, and will fully sustain the truth of the old proverb, "An ounce of prevention is worth a pound of cure." At important terminals a man is usually assigned to this work. However, many things may be noticed by the engineer while the locomotive is in use that might not be observed by the inspector. For this reason engineers are also required to inspect their engines carefully after each trip, and notify the roundhouse foreman in writing of all work which is necessary to be done. They are held responsible for all defects not reported by them. The engineer's report (M. P. Form 95) is of great value to the roundhouse foreman, as it calls his attention to the working of the engine while in service. On the reverse side of the engineer's report is given the certificate of the workman that all repairs have been made which must be

approved by the roundhouse foreman before the engine is put in service.

STOCK KILLED AND INJURED.

In settling claims against a company for damages to property, etc., it is essential that the officials engaged in disposing of these matters should be fully and accurately informed as to the facts in each case. In all cases where the damage is caused by locomotives the engineer's version of the accident must be promptly obtained. In order to prevent the engineer from overlooking any of the circumstances bearing on the case, a form is provided for his use in making a report of each accident.* Thus all the points which have been found valuable in the settlement of other claims may be incorporated in the report, and the responsibility of the company more accurately determined.

KEEPING THE TIME OF SHOPMEN.

An all important feature in the supervision of the affairs of the Motive Power Department is the keeping of and apportioning the time of the employes at the various shops and roundhouses, and accounting therefor. Reasonable safeguards must be enforced—both to secure to the employe the amounts due him, and to insure the company against loss.

In addition to the correct keeping of the account of the company with each employe, his wages must be charged to the thing upon which he is engaged: if repairing locomotive number 100, his wages while so employed should be charged to the repairs of that engine; if engaged in the manufacture of material for store, the expense should be charged to the cost of such material, and so on.

*M. P. Form 96, Appendix.

Therefore upon the completion of each day's work, every employe is required to make a statement of the total number of hours worked by him during the day, and the distribution thereof, showing the number of hours chargeable to each thing worked upon. (See M. P. Form 58, Appendix.) This report forms the basis for the subsequent accounting required to accomplish the above results. The distribution slips are handed to the foreman or deposited in a box provided for that purpose. After being examined by the foreman and all errors corrected, his approval is noted on each slip. They are then sent to the timekeeper for entry in the time-book.

At large shops where the volume of such work justifies it, a separate form is used in reporting the time of employes engaged in the manufacture of material for stock (Form 104). These may be printed on colored paper, so as to distinguish them from the other time slips. They can then be readily sorted, and, after the time is entered in the time-book, given to the cost-clerk, to be used in computing the cost of the material manufactured.

When employes are engaged on "piece-work," their pay being based on the amount of work done, a report (Form 102) showing the number of pieces completed should be made by the foreman in charge of the work. After being approved by the general foreman, or other person in charge, these reports should be forwarded to the timekeeper. To aid in distinguishing them from the other time slips, they should be of a different shape or size, or printed on different colored paper.

Upon receipt of the time slips, properly approved, the timekeeper should enter them in the time-book (Form 97), crediting the employe with the total number of hours worked by him, and charging same to the various accounts for which the expense is incurred.

At the close of the month the total time worked and wages due each man are computed; also the amounts charged to the various accounts. The sum of the distribution should equal the total wages due the employe, and by balancing the several accounts in this manner errors made in entering the total time or the details thereof may be found and corrected. From the time-book the pay roll is written, and the distribution of the charges to the various accounts made.

The time-book used by the foremen in keeping the time of men at less important points, where there is no separate timekeeper, is made up of loose sheets, the required number of pages being bound together at the commencement of the month in covers provided for this purpose. This enables the person making the pay roll for several such shops to bind the different time-books together in one book, making a convenient record. The total time worked by each employe and the distribution thereof should be entered in the time-book each day by the foreman. At the close of the month the total amount due each man is summed up; also the total amounts charged to each of the accounts named. The book is then certified to by the foreman, and forwarded promptly to the proper official, who will enter the time on the pay roll and charge the labor to the proper accounts in his distribution book (Form 106).

NOTE.—As the methods pursued in keeping the time of employes and rendering returns thereof relate more particularly to Disbursements, they are treated of in another volume of the "Science of Railways."

ORDERING MATERIAL.

Experience has demonstrated that the most economical method of handling a company's material and supplies is to keep the principal stock at a general store-

house—confining the stores at the shops and other points along the line to absolute needs. Thus effective supervision is promoted, and economy enforced in the receiving, checking, handling and watching of supplies.

Whenever it is necessary to order material for use at shops or elsewhere, a requisition should be made on the general storekeeper, or other official in charge of the principal storehouse. Such requisition should specify where the material is to be used, and each item should be accurately described, so as to avoid errors in shipping the material. In addition to specifying the quantity wanted, the requisition should show the quantity then on hand, and the amount ordered on previous requisitions but not yet received. This information will enable the approving officer to see whether the order is excessive. To save clerical labor, the requisition is written in triplicate (by the use of carbon sheets), the original or first copy being sent, after approval, to the official on whom it is drawn; the second, to the person who is to receive the material, and the third retained for a record by the maker.* To avoid the labor of transcribing the items in invoicing the material shipped to the local storekeeper, the original copy is also used as an invoice, an impression copy of same being retained by the official filling the requisition.

No material should be delivered to shopmen by the storekeeper except upon written orders signed by the foreman. Such orders should be restricted to immediate needs—the stock being kept in the storehouse where it can be more effectively guarded. In order that all material used at shops may be charged by the storekeeper to the proper accounts, the foreman is

*M. P. Forms 98, 99 and 100, Appendix.

required to specify for what purpose the material is to be used.

Orders for material to be used in the manufacture of articles at shops may be printed on colored paper, so as to distinguish them from the orders for material used for other purposes, if the volume of such business warrants it. As the orders form the basis for writing up the accounts, columns are provided in the form so that the storekeeper may enter thereon the weight, price and amount. (See M. P. Form 101, Appendix.)

Material in store is charged to the storekeeper or other person responsible for its safekeeping and disbursement. As the material is used, the storekeeper records the distribution thereof, entering under such headings as may be prescribed by the officer in charge of the accounts the various items of material chargeable to each. These returns are written up from day to day, as the disbursements are made, and at the end of the month the amounts are summed up and the totals chargeable to the various accounts recapitulated. When completed the distribution book is sent to the proper officer, by whom the items are audited, and afterwards the amounts placed to the debit of the respective accounts, and the storekeeper credited with the gross amount disbursed by him.

Loose sheets are provided for reporting the distribution of material used and labor performed (M. P. Forms 105 and 106, Appendix), in order that the person making the returns may take an impression copy thereof for his office record before forwarding the original to headquarters. These sheets are eyeletted, and should be bound together in book form after being copied, suitable covers being provided for this purpose.

TONNAGE HAULED BY ENGINEERS.

Finally the work performed by engines, as represented by the gross tonnage hauled—and the distance hauled—is all important in scrutinizing the operations of locomotives. This information is obtained from the train reports of conductors, a separate account being kept at headquarters with each engineer. At the close of each month the official in charge of these accounts sends to the Master Mechanics and other interested officials a summary showing the number of tons hauled one mile by each engineer during the month, and such other information relating thereto as may be required. (See M. P. Form 107, Appendix.)

NOTE.—As the practices connected with the handling of material supplies and the accounts connected therewith, refer more particularly to Disbursements, the reader is referred to the volume of the "Science of Railways" treating more particularly of such matters.

CHAPTER IV.

Locomotive and Train Mileage.

Information regarding locomotive mileage is of great value in many ways, but chiefly for ascertaining the relative economy exercised. For this purpose exhibits are prepared which show the average outlay per mile run by locomotives for wages of engineers, firemen, locomotive wipers, hostlers, and laborers at roundhouses; cost of repairs (material and labor being shown separately), supplies—such as tools and cab furniture—quantity and cost of fuel; quantities and cost of oil and waste, etc., etc. The statistics should show (as specified), the average number of pounds of coal, pints of lubricating oil, pounds of waste, and average train tonnage hauled, per mile run. These returns are commonly embraced in what is called the performance sheets of locomotives.

The use made of data regarding locomotive mileage varies on different roads; nor is uniformity observed in classifying the service. Because of this, and to facilitate comparisons, it has been suggested that the mileage of locomotives should be reported under the following specific heads:

Passenger locomotive mileage.
Freight locomotive mileage.
Mixed train locomotive mileage.
Helping locomotive mileage.
Light locomotive mileage.
Switching locomotive mileage.
Work locomotive mileage.

There can be no objection to this classification being further subdivided to meet the preferences of par-

ticular roads—provided such subdivisions may finally be consolidated under the heads named above.

Passenger locomotive mileage embraces revenue passenger train mileage, as hereinafter defined, and the mileage of non-revenue trains of the passenger class, such as pay trains, official trains, complimentary trains, employes' trains, etc.

Freight locomotive mileage embraces revenue freight train mileage, not including the mileage of trains consisting of only a locomotive and caboose "running light." It also includes the mileage of non-revenue freight trains, such as trains hauling company material and supplies.

Mixed train locomotive mileage embraces revenue mixed train mileage.

Helping locomotive mileage embraces the mileage of locomotives while pushing, double-heading or otherwise assisting trains of all classes. It also includes the additional loaded mileage made in doubling hills. It is subdivided into four classes, according to the nature of the service, each of which should be separately reported, viz.: helping passenger trains, helping freight trains, helping mixed trains, and helping non-revenue trains.

Light locomotive mileage embraces that made by locomotives running "light," as when running for water or fuel; running to or from the roundhouse, shops, or trains; running light after pushing, double-heading, or in any similar way assisting passenger, freight, mixed or non-revenue trains; and light mileage made in doubling hills. It also includes the mileage of locomotives when running with only a caboose car attached.

Switching locomotive mileage embraces all loaded or light mileage made in switching cars, except shop or work switching.

Work locomotive mileage embraces the mileage of

locomotives engaged in hauling work trains, such as gravel, ballast, construction, wrecking and repair trains, snow plows and flangers; also the mileage of locomotives employed in shop or work switching.

The rules governing the computation of locomotive mileage are generally as follows:

The mileage of locomotives engaged in hauling trains—except helping mileage and work train mileage—should be based on the actual distance run between terminals, to be computed from the official time-table, as hereinafter prescribed for train mileage.

Helping and light mileage of locomotives should be based on the actual distance run while helping trains or running light, as the case may be.

Switching locomotive mileage is computed at an arbitrary rate of six miles per hour for the actual time while engaged in such service (or such other basis as may be determined from time to time.) Mileage for switching and other work done incidentally enroute at way stations is not generally allowed, except in the case of locomotives of local freight trains when employed in switching for one hour or more at a station—in which case they are allowed switching mileage at the rate of six miles per hour for the actual time so employed. No allowance is usually made when the time thus engaged is for less than one hour at any particular station.

Work locomotive mileage is arrived at in the same manner as prescribed for work train mileage.

While usages differ in regard to the classification of locomotive mileage on different roads, nevertheless there is practical unanimity in reference to what constitutes the different classes of service, viz.: passenger, freight, switching and work. But there is nothing so fixed or necessarily arbitrary in connection with the matter as to enforce particular methods, whether or no.

If for any reason it is desierd to consolidate the different classes of locomotive mileage so as to show only the four kinds of service as named above, the following classification has been suggested:

Passenger mileage to include passenger locomotive mileage; a proportion of the mixed train locomotive mileage, based on the work performed; the mileage of locomotives helping passenger trains; and, finally, the light mileage made by locomotives on account of passenger service.

Freight mileage to include freight locomotive mileage; a proportion of the mixed train locomotive mileage, based on the work performed; the mileage of locomotives engaged in helping freight trains; and, last, the light mileage made by locomotives on account of freight service.

Switching and work mileage should include the switching locomotive mileage and the work locomotive mileage as previously defined.

Train Mileage.

The following classification of train mileage, it is of course to be understood, may be further subdivided or extended to meet the preferences or special needs of a company; but no change is advisable that will prevent the ready compilation of the statistics required under the general heads prescribed by the government for the use of railroad companies in making their returns.

The subdivisions as given below represent the ideas of experts upon the subject, and will, generally, be found sufficient for all practical uses. For explanatory purposes here, a "train" may be defined as as consisting of one or more cars coupled together, drawn by a locomotive, running between specified terminal points in accordance with an authorized schedule or time table, or under special orders from the operating officials of a company.

Each train and each section of a train operated by a separate train crew, is considered a separate train, whether hauled by one or more locomotives, either for the whole or only a part of the distance between the terminal stations.

Train mileage is divided into two general classes: revenue train mileage, which includes the mileage of all trains from the operation of which the company receives an income—directly or indirectly; and non-revenue train mileage, which includes the mileage of all trains operated by the company from which no income is derived.

Revenue train mileage is subdivided into passenger train mileage, freight train mileage, and mixed train mileage. These may be defined in detail as follows:

Passenger train mileage embraces the mileage of trains run to transport revenue-earning passengers, and to carry baggage, mail, express matter, and other traffic classed as passenger business—not including any trains which regularly include one or more cars

devoted exclusively or principally to carrying revenue-earning freight.

Freight train mileage embraces the mileage of trains run to transport revenue-earning freight—excluding all trains which regularly include one or more cars devoted exclusively or principally to revenue passenger business. It also includes the mileage of trains of empty freight cars, or of trains running light—*i. e.*, consisting of a locomotive and caboose.

NOTE.—When milk cars are hauled in a passenger train, the mileage of the train is, for convenience, generally embraced under the head of passenger train mileage. When milk or express cars are hauled in a freight train (and their earnings are classed as freight earnings) the mileage of the train is similarly included under the head of freight train mileage.

Mixed train mileage embraces that of trains carrying both revenue passengers and revenue freight—each car being exclusively or principally devoted to either passenger business or freight business. Freight trains that haul no passenger cars, but transport passengers in caboose or way cars, are not called mixed trains, but their mileage is included under the head of freight train mileage.

Non-revenue train mileage embraces the mileage of trains not directly connected with the earning of revenue, such as pay trains, official trains, complimentary special trains, trains run to convey employes; trains hauling the company's material and supplies gravel, ballast, construction, wrecking and repair trains, snow plows and flangers and so on. As a rule the mileage of non-revenue trains is not kept separate as to the classes named above, but given in gross under the general head of non-revenue train mileage.

NOTE.—Revenue passenger trains and revenue mixed trains may incidentally carry private or official cars, work or service cars, or cars of related classes, for which no charge is made; and similarly, revenue freight trains and revenue mixed trains may incidentally carry cars containing railway material and supplies, or other freight not earning revenue; but only whole trains of such non-paying cars should be regarded as non-revenue trains and classed accordingly.

The mileage made in switching trains and cars is not properly included under the head of train mileage. Such statistics should be reported under the head of "switching locomotive mileage," defined elsewhere.

In computing revenue train mileage the mileage allowed is based on the actual distance run between terminals, as shown by the official time table. There should be nothing added to this distance to cover switching or other work at way stations, or for service of helper or pusher engines, or extra engines on double or triple head trains, or for any distance run by the engine in excess of that run by the train, such as the distance from the round house to the train terminal, doubling hills, running for fuel or water, etc.

The same rule is observed in computing mileage of passengers and tons of freight, and car mileage.

The mileage of non-revenue trains should be based on the actual distance run between terminals, the same as directed for revenue trains. When work trains are run between terminals and do not work at some specified point or within specified limits, they are allowed the actual mileage made, the same as other trains. When run to a certain point for the purpose of working at that point or within specified limits, they should be allowed the actual mileage made under running orders, and in addition an arbitrary mileage of six miles per hour (or whatever may be agreed upon), for the time they actually work at the point designated or within the working limits specified.

From the foregoing it will be seen that train mileage takes no account of the gross work done, such as the number of cars moved, passengers carried, or tonnage hauled. A train is a train—whether long or short, heavy or light; and it is for this reason that train mileage figures alone are in themselves of no great value.

But when used in conjunction with other returns, operating efficiency may in a measure be determined; such statistics being of value to the officers of a company in the supervision of the movement of traffic, etc., etc.

For example, the expense of running a light train is proportionately greater than the expense of operating a heavier train—taking into consideration the relative tonnage moved—because many of the expenses incurred in connection with the movement of a train are practically the same, regardless of the gross tonnage handled. The expense for wages of enginemen and train crew, the cost of the supervision of a train's movement over the road, the expense of looking after and caring for the engine at terminal points, the maintenance of the roadway, and so on,—all large items of expense—are not increased in proportion with an increase in the load hauled by a train. If, therefore, the number of loaded freight cars hauled per train mile—the gross tonnage of revenue freight moved per train mile—can be increased, the earning power of the road is thereby heightened; and it is in determining what has been accomplished along such lines that locomotive and train mileage statistics are of value.

NOTE.—In another volume relating to Cars, a classification is made of statistics found to be of practical value, such as the mileage of trains, the cars they haul, the loads they carry, etc

CHAPTER V.

FORMS AND EXHIBITS USED IN THE SUPERVISION OF LOCOMOTIVES.

The value of these in connection with the motive power department cannot be overestimated, for through them those responsible for the conduct of business are not only able to direct operations over a wide territory, from hour to hour, intelligently, but afterwards to sum up the results secured. These results are judged according to attainable standards of work, through comparisons and otherwise, and commendation or reproof are based thereon. It will be seen, therefore, that they are of inestimable value and that, without them, there could be neither effective supervision nor intelligent co-operation. It is apparent, therefore, that they should be minute and exhaustive, and should be faithfully made and intelligently studied by those concerned. Through them every phase of the service is discerned, including the placing of locomotives and knowledge of their needs and performances.

No one can study the returns and exhibits of railway operations without being impressed with their necessity and great value in practical operations. To searchers after knowledge they not only afford insight into the workings of the great departments, but have additional value in the things they suggest.

The returns and exhibits embodied herein, measurably represent the needs of those in charge of locomotives. They have been of slow growth and portray the evolution of the service in this respect. For, at one time, there may be said to have been neither returns nor exhibits of any kind regarding the working of locomotives. That was in the beginning when chaos

reigned, compared to the systematic supervision and discharge of business exercised at the present moment.

It is probable that these forms and exhibits represent but a phase of growth; that with time and greater knowledge and experience they will be bettered and others added. This is the experience of every great and growing business. What seems perfect today is found to be deficient in some respect tomorrow. That is because men are wiser today than they were yesterday. However, so far as these forms go, they are intended to furnish those in charge such data as is esteemed necessary to enable them to judge quickly and intelligently of what is going on, and of what the service needs. Through them and by comparisons, waste, improvidence and ineffective service are discerned and remedied. And it is not too much to say that it is through them that economy in the use of fuel, oil, waste and the working and repair of engines are more clearly traced and waste corrected, than through any other medium of information or advice attainable by those in charge.

Specific knowledge is all important when we remember how imperfect the locomotive is and how complicated are its workings, notwithstanding all the improvements that have been made in its construction and working. Because of this and their extended and widely separated use, carefully organized supervision is necessary to their effective working. It is not only necessary when anything is wrong in connection with their operation that it should be known, but that it should be known quickly if ineffective service and extravagance are to be prevented.

The transfer of engines from one part of a road to another is of constant occurrence, and effective service from the standpoint of profit and public accommodation is secured, or otherwise, through the intelligent action and celerity exercised by those in charge. The

sources of information at the disposition of the motive power department are such as to secure such action, and, in making transfers, to do so at the least possible inconvenience and cost to the service. Thus, among the returns, will be found those stating the location of locomotives; their condition; locomotives in shops; when repairs on particular locomotives will be completed; those available for service, etc.

Another feature is the immediate information certified to those in charge, of engine failures, whereby trains are delayed or danger incurred or threatened. And as there are innumerable causes for such failures each must be carefully scrutinized. As aids in this direction, returns are required specifically stating the cause of failure; the engineers' report of delays; the causes thereof, and such attendant and supernumerary returns as a proper understanding of the subject requires. From the reports of engine failures, those in charge are able to determine with approximate accuracy whether failures are due to defects in the machine, or lack of skill or care upon the part of those in charge. If due to the machine the break-down is not only of interest in itself, but suggestive in regard to appliances of like nature in other machines; and so valuable knowledge is oftentimes gained through these returns of break-downs. If, on the other hand, they are due to neglect or ignorance upon the part of those in charge, knowledge of the fact is valuable because of the curative discipline necessary to prevent a recurrence of the accident.

Another exhibit of special importance recounts the performance of locomotives. Through these repairs made, amount of work done and cost thereof and the relative economy exercised, are ascertained. At one time—and, indeed, measurably so now—comparisons were based on the mileage of engines. This, however, has been supplemented by comparisons on

the load hauled, which more nearly portrays the work done and, therefore, more fairly represents value received. Statistics of the performance of locomotives (and consequently of trains), it may be said, tend more and more with the mangement of railroads, to comparisons based on the paying load hauled; what is termed the ton mile basis in the case of freight. Thus the management is kept advised as to whether cars are fully loaded and the full complement hauled in trains. However, from the standpoint of motive power officials, statistics showing the total weight hauled—dead and paying—is all important in judging of the relative cost of operating engines. The motive power department is not responsible for the number or frequency of trains, nor for neglect or inability of operating officials to fully load cars. Its objective point or basis of comparison is the gross load hauled, and on this basis judgment is formed. The motive power department, it may be said, not only knows the work each engine performs and items of cost, but how one division of the line compares with another in this respect, and so on. Thus, through these and similar exhibits, every one is stimulated to make the best showing possible; to get all out of the locomotive that can be achieved through intelligent effort in loading and handling cars, and finally, in the economical working of the power used in doing the business.

In order to further effective supervision of locomotives it is found useful to keep specific accounts with each engine, viz.: mileage, fuel, oil, waste, tallow, engine supplies (and tools), cost of material used in repairs, cost of labor including superintendence, time and mileage record of wheels under locomotives, time and mileage record of steel tires on engine truck wheels*, and finally, the tonnage hauled. This last is

*In many cases, manufacturers of locomotive wheels and steel tires (and other kinds of wheels in some cases), guarantee that they will make certain mileage. Record must therefore be kept in order to enforce terms of guarantee if wheels fail.

all important, for it forms to a certain extent, the basis of determining relative skill and economy exercised by engineers; and, to pursue the inquiry further, the relative expenses of engines—as specified above.

To particularize, the sources of information that the accompanying returns point out are not only explicit, but suggest other and special lines of inquiry. Mediums of information may be multiplied almost indefinitely; those in charge will ever wish to know the whys and wherefores concerning all things affecting cost or efficiency of service. Averages will not suffice; they will wish to analyze and multiply their sources of information to the utmost. Thus many will not only require to know the tonnage hauled and the cost thereof, but the expenditure of forces involved. They will require to know daily or periodically the number of locomotives of each class in service (passenger, freight, switching, etc.), the gross quantities of fuel consumed —as well as the cost thereof—by each class of service; the number of pounds of fuel consumed per engine mile; the number of pounds of fuel consumed per car mile; the gross quantities consumed—as well as the cost—of valve, engine and car oil used on locomotives, and the quantity and cost thereof per mile run; the total number of pounds—as well as the cost—of waste used, and the quantity and cost thereof per mile run; the cost of engine service (including enginemen, round house men and engine supplies) per mile run; similarly the cost of engine service per car mile; the cost of repairs of engines (separately for material and labor) per mile run; the cost of repairs of engines (separately for material and labor) per car mile; the gross tonnage moved by locomotives. Not only will those responsible for locomotives desire to know all this in regard to cost per mile run by locomotives and per car mile, but as I have already explained they will also wish to know what the expenditure of material and cost of

labor are on the basis of tons hauled one mile—for passenger and freight service separately.

Information of this nature, in addition to that referred to elsewhere herein, directly or indirectly, will suggest itself as being valuable—if not absolutely necessary—to many having charge of the supervisory work of locomotives. No two men—it is probable will place the same value on data of this and similar nature. Each will enforce, for permanent use or temporary expediency, such means of enlightenment as he can use advantageously or as the temporary exigencies of the service point out. And in this connection they will always consider the cost of the information—the clerical labor and expense it involves—in connection with its value, when obtained.

Effort has been taken in arranging the forms and exhibits which follow, not only to explain the purpose that each is intended to conserve, but also every necessary particular in regard to how the exhibit should be made and what it should contain. These directions, in fact, are so explicit that in the majority of cases it will not need long or technical experience to understand and compile them. Like accounts generally, if properly compiled, they have only to be studied to be understood. This last cannot be too strongly impressed on those who would keep themselves advised in regard to details of railway operations. Men often complain that they cannot understand accounts. This does not arise from lack of intelligence but from indisposition to study the accounts attentively. For there is nothing done by man that is so clear as accounts when thus stud-

ied. Nor, indeed, that furnish more valuable and needed information in the case of great and widely extended properties.

In regard to the forms and returns of a statistical nature, or those used for other purposes of Locomotive Supervision, no two roads, it is probable, will conform exactly to each other, either in the number or character of the exhibits. Wherever thoroughness is observed, however, they will be generally similar. The number and complexity (and oftentimes general similarity) of the returns will confuse and perplex the novice; to him they will very likely have the appearance of exaggeration, or, it may be, duplication of work. This, however, is only apparent when the situation and its needs are considered. Every one who is responsible for locomotives must be kept advised in regard to the same in order that he may perform his duties effectively; or, in the event he neglects to do so, that the omission may be noticed and corrected. Thus, the foreman of a shop must have certain information, we will say, in regard to a particular phase of locomotive business; the master mechanic of that group of shops must also have information of a like nature, but differing in some respect; then the Superintendent of Motive Power and Machinery must also be advised in regard to the matter, not only for that particular shop but for the division, and for the whole road. Moreover, the General Manager or other operating official also requires specific information in regard to many things in order that his supervision of affairs may be effective. Thus, there will be four or more officials

to be advised of occurrences, but no two, perhaps, requiring exactly the same details. And so, returns and exhibits must always be multiplied to conform to the many and varied requirements of those responsible for operations. And it may be truly said that the greater the knowledge and means of enlightenment and supervisory methods that responsible officials are acquainted with the more efficient and economical will be the conduct of the service—provided they make use of their knowledge. And because this is so, grave interest and value attach to the accompanying exhibits, which may seem so multiplied and perplexing to the casual examiner

CHAPTER VI.

LIST OF FORMS AND EXHIBITS. SPECIFIC BLANKS.

NOTE.—In estimating the usefulness of these forms the particular official directed herein to make the return or receive it is unimportant. The organization of no two roads will agree, throughout, in respect to such matters. Thus, returns that are made by the division superintendent on one road may be made by the train dispatcher, master mechanic, or foreman of another; and this is equally true of the officials to whom returns are rendered. Such matters conform to environment; to whatever form of organization is thought best. It is the return itself that is interesting and important.

No.

1. Foreman's weekly report to the Master Mechanic of locomotive boilers washed out.
2. Master Mechanic's weekly report to Superintendent of Motive Power and Machinery of the location of locomotives.
3. Weekly report by the Superintendent of Motive Power and Machinery to interested officials of the total number of locomotives of each class on the different divisions.
4. Weekly report by the Superintendent of Motive Power and Machinery of the location of each locomotive.
5. Master Mechanic's monthly report to the Superintendent of Motive Power and Machinery of the condition of each engine on his division.
6. Monthly record of the Superintendent of Motive Power and Machinery of condition of each engine on each division.
7. Monthly record of the Superintendent of Motive Power and Machinery of the condition of the different classes of engines on each division.
8. Master Mechanic's report of repairs made on particular engines.

9 10, 11. Shop Foreman's report to his superior of repairs on particular engines.

12. Master Mechanic's report of cost of repairs on particular engines.

No

13. Master Mechanic's monthly summary to the Superintendent of Motive Power and Machinery in regard to heavy repairs made on engines.
14. Foreman's weekly report of Locomotives in shop.
15. Definition of what constitutes engine failures.
16. Train Dispatcher's daily report of engine failures.
17. Engineer's report to Master Mechanic of delays on each trip.
18. Master Mechanic's ten days report to the Superintendent of Motive Power and Machinery of engine failures.
19. Monthly record of the Superintendent of Motive Power and Machinery of particulars (cause) of engine failures on each day of the month.
20. Monthly summary of the Superintendent of Motive Power and Machinery of cause of engine failures on each division.
21. Locomotive Engineer's trip report of time worked.
22. Train Dispatcher's daily record of train movements.
23. Engineer's daily report of switching time.
24. Agent's report of time worked by switch yard crews.
25. Engineer's monthly report of time worked.
26. Division time book of Locomotive Engineers giving particulars of the service of each.
27. Engine house register.
28. Storekeeper's monthly report to the Superintendent of Motive Power and Machinery of delayed and over time allowed engineers and firemen.
29. Monthly record of the Superintendent of Motive Power and Machinery of the gross cost of delayed and over time on each division.
30. Monthly statement of locomotive mileage on each division.
31. Monthly report of locomotive mileage (classified) of each engine.
32. Monthly record of the mileage of each engine.
33. Monthly report of particulars of cost of repairs of each locomotive.
34. Monthly record of repairs on each locomotive.
35. Monthly report for the Superintendent of Motive Power and Machinery of the miles run and cost of repairs of each engine.
36. Monthly report for Division Master Mechanic of mileage and cost of repairs of each locomotive on his division.
37. Record of mileage (classified) and cost of repairs of each locomotive.
38. Form of coal tickets used on engines.
39. Monthly report of fuel delivered at each point to locomotives.
40. Monthly summary of fuel delivered to locomotives.
41. Form of oil and waste tickets used on engines.
42. Monthly report of total amount of oil and waste delivered to locomotives on each division.
43. Round House Foreman's monthly report of the number of engines wiped daily.

No.

44. Monthly summary of charges to various operating accounts for material and labor account of engines on each division.
45. Locomotive Report—particulars of service and cost for repairs, supplies and labor.
46. Foreman's monthly report to Master Mechanic of cast iron truck and tender wheels applied to and removed from locomotives.
47. Monthly record of Superintendent of Motive Power and Machinery of particulars of each defective cast iron engine and tender wheel removed.
48. Monthly summary of the Superintendent of Motive Power and Machinery of the gross number of defective cast iron locomotive wheels removed, made by different manufacturers.
49. Monthly report of the Superintendent of Motive Power and Machinery to the Purchasing Agent of defective cast iron wheels removed from locomotives and by whom made.
50. Monthly report of the Superintendent of Motive Power and Machinery of wheels that have failed to meet guarantees of makers.
51. Record of the Superintendent of Motive Power and Machinery of engine truck and tender wheels applied to and removed from each locomotive.
52. Shop Foreman's monthly report to the Master Mechanic of particulars of steel tired engine truck and tender wheels applied to or removed from locomotives.
53. Index to record of steel tired engine truck wheels.
54. Record of Superintendent of Motive Power and Machinery of steel tires on engine truck wheels.
55. Monthly report to the Superintendent of Motive Power and Machinery of engine driving wheel tires applied and removed.
56. Index to driving wheel tire record.
57. Record of Superintendent of Motive Power and Machinery of driving wheel tires.
58. Daily report of distribution of shop labor of each man.
59. Master Mechanic's monthly statement to Superintendent of Motive Power and Machinery of comparative cost of labor
60. Shop Foreman's monthly report to Master Mechanic of number of men of each class of labor employed during the month and wages paid.
61. Master Mechanic's monthly report to Superintendent of Motive Power and Machinery of the total number of men of each class of labor employed on his division during the month and wages paid.

No.

62. Summary made by Superintendent of Motive Power and Machinery for the General Manager of the total number of men of each class of labor and wages paid on whole road.

Inspector's reports (as per diagrams) of locomotive breakages of different parts as specified in Returns 63 to 78.

63. Pilot coupler.
64. Plate coupler.
65. Master car builder's coupler. (M. C. B.)
66. Axle.
67. Driving box and brass.
68. Cylinder heads.
69. Equalizer. Equalizer Stand. Spring Hangers.
70. Eccentric, eccentric strap, eccentric rod.
71. Side rod, main rod and rod strap.
72. Piston and piston rods.
73. Valves, valve yokes and rocker shaft.
74. Cross heads.
75. Crank pins.
76. Broken stay-bolts.
77. Miscellaneous, used where diagram return is not provided.
78. Condition of locomotive boiler.
79. Inspector's record of inspection of stationary and locomotive fire-box stay-bolts.
80. Inspector's monthly report of inspection of stationary and locomotive fire-box stay-bolts.
81. Inspector's report of periodical inspection of stationary boilers.
82. Inspector's report of inspection of air and steam gauges and safety valves.
83. Inspector's report of changes and repairs of stationary boilers.
84. Shop Foreman's report to Master Mechanic of valve motion of engines.
85. Monthly report of each engineer's service, viz.: Total miles run by locomotives under his charge, tons hauled and fuel consumed.
86. Statement of mileage made by each engineer to pint of lubricating oil.
87. Master Mechanic's report to Superintendent of Motive Power and Machinery of condition of tools and machinery.
88. Form of application made by those seeking employment on engines.
89. Master Mechanic's notice of vacancies in runs and service.
90. Notice of Superintendent of Motive Power and Machinery of those authorized to operate locomotives.
91. Form of release to be signed by minors and their legal guardians.
92. Certificate given on completion of apprenticeship.
93. Master Mechanic's weekly report to Superintendent of Motive Power and Machinery of average terminal delays of freight engines and the cause therefor.

No.

94. Engineer's requisition for supplies.
95. Engineer's report to Round House Foreman of condition of engines at end of each trip.
96. Engineer's report to Master Mechanic of particulars of stock killed or injured.
97 General time book of particulars of hours worked by each man, rate of pay, wages and on what labor was expended.
98 Requisition for and invoice of material.
99 Notice of material ordered.
100 Record of material ordered.
101 Shop order for material.
102 Report of piece work performed by each employe.
103 Form of application for employment in shop.
104 Daily distribution of labor for manufactured material work.
105 Distribution blank for material used.
106 Distribution blank for labor performed.
107 Monthly Statement of the tonnage haul of engineers and average of number of tons hauled per train.

APPENDIX.

MOTIVE POWER DEPARTMENT FORMS.

M. P. Form 1

FOREMAN'S WEEKLY REPORT TO THE MASTER MECHANIC OF LOCOMOTIVE BOILERS WASHED OUT.

At ..... For the Week Ending ..... 19.....

NOTE—This report is to be made on Monday of each week by all Round-House Foremen, and sent to the Division Master Mechanic, who, after making a record of same, will forward the report to the Superintendent of Motive Power and Machinery, by whom a like record is kept.

Sunday	Monday	Tuesday	Wedn'sd'y	Thursday	Friday	Saturd'y
Eng Nos.	Eng Nos.	Eng Nos.	Eng Nos.	Eng Nos.	Eng Nos.	Eng Nos.

M. P. Form 2

MASTER MECHANIC'S WEEKLY REPORT TO SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF THE LOCATION OF LOCOMOTIVES.

On.....Division. For the week ending.....19.....

NOTE—This report is to be made by each Master Mechanic of all engines on his division. It must be sent to the Superintendent of Motive Power and Machinery on Saturday of each week.

In the column headed "How and where employed" should be shown the kind of service the engines are engaged in and the points between which they run.

In the case of engines engaged in switching service the points where the work is performed should be given.

The report should also show the engines on each division that are in the shop for repairs; also what repairs are needed to put each engine in running order.

Nos. of Engines in Working Order	How and Where Employed	Nos. of Engines in Shop for Repairs	Date sent into Shop	Repairs and Alterations Necessary to put each Engine named in Running Order	Date Engine is expected to be Ready for Service

M. P. Form 3.

WEEKLY REPORT BY THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY TO INTERESTED OFFICIALS, OF THE TOTAL NUMBER OF LOCOMOTIVES OF EACH CLASS ON THE DIFFERENT DIVISIONS.

For the Week Ending ..... 19.. .....

NOTE—This exhibit is made on Monday of each week in the office of the Superintendent of Motive Power and Machinery. It is a summary of the Master Mechanics' weekly reports, Form 2, and shows the number of engines in the different kinds of service on each division, and the number out of service for the reasons stated.

DIVISIONS	NUMBER OF ENGINES										
	In Service					Not in Service					
	Passenger	Freight	Construction	Switching	Total	Undergoing Repairs	Laid Up		Total	Limbering Up or En Route	Total
							For Repairs	Awaiting Service			
TOTALS											
Nos. of Leased Engines Leased to.....											
Vacant Nos. to be Replaced											
GRAND TOTAL											

M. P. Form 4

WEEKLY REPORT BY THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF THE LOCATION OF EACH LOCOMOTIVE

For the week ending 19

NOTE.—This report is compiled in the office of the Superintendent of Motive Power and Machinery on Tuesday of each week. It is a summary of the Master Mechanics' weekly reports, "Form 2," and shows the location of all the locomotives belonging to the company at the end of each week. The engine numbers are represented by the numbers shown vertically and horizontally hereon in print; those shown vertically representing units and tens and those shown horizontally representing hundreds, as illustrated below.

Each Division is also represented by a number, and the number of the Division on which an engine is located should be shown in the square corresponding to that engine number, as illustrated below.

Engines that are out of service on account of being in shop or laid up for repairs should be so indicated in the square corresponding to such engine number by the letter "S" or "L" being shown above the number representing the division on which such engine is located. Engine numbers that are vacant on account of engines being cut up should be indicated by the letter "C" being shown in the proper square above the number of the division on which such engines were last located, and should be shown in like manner until such engines have been replaced.

For example, Engines Nos. 803 and 1048 are on Division No. 1; Engines Nos. 56 and 1172 are on Division No. 2; Engine No. 109 is in shop on Division No. 3, and Engine No. 330 is laid up on Division No. 4, the location of these engines being designated in the blank below.

The number of the Division for all engines numbered between 1 and 100 should be entered in the column at the left of the numbers shown vertically and those numbered over 100 should be shown at the right and in the proper column.

	1	2	3	4	5	6	7	8	9	10	11	12	13			1	2	3	4	5	6	7	8	9	10	11	12	13
1															51													
2															52													
3									1						53													
4															54													
5															55													
6														2	56													
7															57													
8															58													
9	3														59													
10	3														60													
11															61													
12															62													
13															63													
14															64													
15															65													
16															66													
17															67													
18															68													
19															69													
20															70													
21															71													
22															72										2			
23															73													
24															74													
25															75													
26															76													
27															77													
28															78													
29															79													
30															80													
31															81													
32															82				1									
33															83													
34															84													
35															85													
36															86													
37															87													
38															88													
39															89													
40															90													
41															91													
42															92													
43															93													
44															94													
45															95													
46															96													
47															97													
48										1					98													
49															99													
50															100													

M. P. Form 5

MASTER MECHANIC'S MONTHLY REPORT TO THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF THE CONDITION OF EACH ENGINE ON HIS DIVISION

.....Division Date.....19.....

NOTE—This report is to be made on the first day of each month by the Master Mechanic for the Superintendent of Motive Power and Machinery. It must include all locomotives on the division and show the condition and other particulars for each engine upon the date report is made.

Engine Number	Size of Cylinder	Date when General Repairs were Made	Mileage since last General Repairs (not incl. last month)	CONDITION OF				Number of months before repairs will be necessary. Other remarks
				Machinery	Flues	Fire Box and Boiler	Tires	

M. P. Form 6.

MONTHLY RECORD OF THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF CONDITION OF EACH ENGINE ON EACH DIVISION.

..... Division. For the month of ..... 19.....

NOTE—This exhibit is compiled monthly in the office of the Superintendent of Motive Power and Machinery from Form 5. It shows the number of each engine in the various columns according to the condition of the locomotive

In the column for vacant numbers, the numbers of the locomotives that have been sold, scrapped or destroyed should be entered each month in the report for the division to which such engines were last assigned; this until such numbers shall have been replaced.

CONDITION			In Shop	Vacant Numbers to be Replaced
Good	Fair	Poor		

M. P. Form 7

MONTHLY RECORD OF THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF THE CONDITION OF DIFFERENT CLASSES OF ENGINES ON EACH DIVISION.

MONTH OF.....19....

NOTE—This report is made in the office of the Superintendent of Motive Power and Machinery and forwarded to the General Manager on the fourth day of the following month. It is a summary of Form 6. It shows the condition of locomotives engaged actively in each kind of service on the different divisions: the number in shop for repairs; the number for which special disposition has been made; the number that has received general and heavy repairs; also percentage of engines in different conditions in each service and number in shop or disposed of.

DIVISIONS	NUMBER OF LOCOMOTIVES IN EACH SERVICE																		TOTAL FOR ALL SERVICES
	In Good Condition			In Fair Condition			In Poor Condition			In Shop			Sold or Cut Up			Total in each Service			
	Pass.	Frt.	Switch	Pass.	Frt.	Switch	Pass.	Frt.	Switch	Pass.	Frt.	Switch	Pass.	Frt.	Switch	Pass.	Frt.	Switch	
TOTAL																			

NUMBER OF ENGINES THAT RECEIVED GENERAL AND HEAVY REPAIRS.

SHOP	ROAD		SWITCHING		TOTAL
	Gen'l	Heavy	Gen'l	Heavy	
TOTAL					

PERCENTAGE OF ENGINES IN DIFFERENT CONDITIONS IN EACH SERVICE

CLASS OF SERVICE	No. of Engines	PERCENTAGE OF ENGINES				
		In Good Condit'n	In Fair Condit'n	In Poor Condit'n	In Shop	Sold or Cut Up
Passenger						
Freight.						
Switching.						
TOTAL...						

M. P. Form 8

MASTER MECHANIC'S REPORT OF REPAIRS MADE ON PARTICULAR ENGINES.

.....Shops. Date .....19..

Engine No..... .....Class .....

NOTE.—This form enumerates in detail the various parts of an engine. A report of this kind is to be made for each engine receiving repairs amounting to $25.00 or more. When new parts are applied, such parts should be prefixed by the letter "X"; parts that are repaired by the letter "O." It should show the date the engine entered the shop, and the date when ready for service; also the total cost of material and labor expended in the repairs as shown at the end of the report.

When parts are repaired or renewed of which there are two or more of the same name, the report will specify which parts they are; as right or left, front, middle or back, right front or left front.

When an engine is to be sent to the principal shop of the road for extensive repairs, the master mechanic should use this form to report all work necessary in repairing the engine. The report should be sent to the Superintendent of Motive Power and Machinery, who will, after approving such repairs, forward the report to the superintendent of the shop, thus enabling the latter to order material not in stock so as to guard against any delay in making the repairs. This will enable him to maintain a regular time schedule for repairing engines.

When the engine has been repaired the superintendent of the shop will make a report on this form showing in detail what repairs have been made. For engines repaired at local shops, the report will be made by the foreman in charge and forwarded to the master mechanic.

All reports of this form must be sent to the Superintendent of Motive Power and Machinery to be kept on file in his office.

BOILER AND FIRE BOX.

1. Boiler,
2. Boiler Braces,
3. First course from Arch,
4. Second course from Arch,
5. Third course from Arch,
6. Slope Sheet,
7. Roof Sheet,
8. Right Side Sheet,
9. Left Side Sheet,
10. Back Head Sheet,
11. Throat Sheet,
12. Front Flue Sheet,
13. Waist Sheet,
14. Dome,
15. Dome Braces,
16. Dome Cap,
17. Test Pressure, lbs.,
18. Pressure Allowed, lbs.,
19. Weight of Scale Removed, lbs.,
20. Fire Box,
21. R. S. Sheet—Thickness Make
22. L. S. " " "
23. Door, " " "
24. Crown, " " "
25. Flue, " " "
26. Arch Tubes, Number new, Which
27. Mud Ring,
28. Stay Bolts, Number new,
29. Crown Bars, Number new,
30. Crown Bar Braces,
31. Crown Bolts,
32. Flues, Number new, No. reset
33. Combustion Tubes,
34. Brick Arch,
35. Grates,

BOILER ATTACHMENTS.

36. Ash Pan,
37. Ash Pan Dampers,
38. Deflecting Plate,
39. Extended Front,
40. Fire Door and Frame.
41. Front End Ring,
42. Front End Door,
43. Netting,
44. Petticoat Pipe,
45. Safety Valves, No., Size and Make
46. Smoke Arch,
47. Smoke Stack,
48. Smoke Burners, Kind,
49. Spark Hopper, Cinder Hopper,
50. Whistle,
51. Wash-out Plugs.

COCKS.

52. Blower,
53. Blow Off, No., Kind,
54. Cylinder,
55. Gauge,
56. Heater,
57. Surface
58. Steam Heat,
59. Syphon,
60. Oil Oilers,
61. Sight Feed Lubricator, No. Kind,
62. Cock Stand,

CYLINDERS.

63. Cylinders, } Which,
Cylinders, } Which, Bushed.
Cylinders, } Which, Bored,
64. Cylinder Heads, Which,
65. Cylinder Casings, Which,
66. Cylinder Jackets,

PISTONS.

67. Spiders, Which,
68. Followers, Which,
69. Bull Rings, Which,
70. Packing, Which, Kind,
71. Rods, Which, Mat'l,
72. Glands, Which,
73. Rod Packing, Which, Kind,

CROSS HEADS, Etc.

74. Cross Heads, Which,
75. Gibs,
76. Guides, Which,
77. Guides, Yokes, Which,
78. Guide Blocks, Which,

DRIVING WHEELS, Etc.

79. Wheels, Which, Mat'l,
80. Axles, Which, Mat'l,
81. Boxes, Which, Mat'l,
82. Brasses, Which,
83. Shoes, Which,
84. Wedges, Which,
85. Waterline, Which,
86. Tire Thickness, Diam.,
87. Tire Maker,
88. Crank Pins, Which, Mat'l,
89. Springs, Which, Make,
90. Hangers, Which,
91. Equalizers Which,

ENGINE TRUCK.

92. Truck, Which,
93. Boxes, Which, Mat'l,
94. Brasses, Which,
95. Frames,
96. Pedestals Which,
97. Springs, Which, Make,
98. Hanger, Which,
99. Equalizers, Which,
100. Top Center,
101. Bottom Center,
102. Engine Truck Wheels, Number new,

FEED WATER.

103. Injectors, Which,
104. Kind and Size—Right, Left,
105. Checks, Which,
106. Size and Make,
107. Feed Pipes,
108. Delivery Pipes,

RODS.

109. Main Rods, Which, Mat'l,
110. Brasses, Which, "
111. Straps, Which,
112. Bolts, Keys,
113. Side Rods, Which, Mat'l,
114. Brasses, Which, "
115. Straps, Which, "
116. Bolts, Which, Keys,

STEAM CHESTS.

117. Chests, Which,
118. Covers, Which,
119. Casings, Which,
120. Air Valves, Which,

SLIDE VALVES.

121. Valves, Which,
122. Kind,
123. Lap, Steam, Exhaust,
124. Lead,
125. Seats, Which, Kind,
126. Yokes, Which,
127. Stems, Which,
128. Stem Glands, Which,
129. Stem Packing, Which, Kind,

VALVE GEAR.

130. Links, Which,
131. Rocker Arms, Which,
132. Rocker Boxes, Which
133. Eccentrics, Which,
134. Straps, Which, Mat'l,
135. Rods, Which,
136. Reverse Lever,
137. Quadrant,
138. Reach Rod,
139. Valve Rod, Which,
140. Tumbling Shaft,

STEAM PIPES, Etc.

141. Steam Pipes, Which,
142. Exhaust Pipes,
143. Ex. Nozzles, Kind, Size,
144. Tee Pipe,
145. Dry Pipe,
146. Stand Pipe,
147. Throttle Valve,
148. Throttle Lever,
149. Throttle Stem,

MISCELLANEOUS.

150. Air Signal and Piping,
151. Bell, Bell Ringer,
152. Bell Stand,
153. Brake, Air, Size of Pump,
154. Bumper Girths, Beam,
155. Cab,
156. Cab Brackets,
157. Cab Deck Castings, Wood Deck,
158. Chafing Iron,
159. Dome Casing,
160. Frames, Frame Castings,
161. Frame Jaws and Braces,
162. Hand Railing,
163. Hand Rail Columns,
164. Head Light, Front, Back,
165. Head Light Brackets,
166. Jacket,
167. Lagging, Kind,
168. Painting,
169. Pilot, Front Back
170. Pilot Coupler—Automatic,
171. Running Board,
172. Running Board Brackets,
173. Sand Box,
174. Sand Box Casing,
175. Sander—Kind,
176. Steam Gauge,
177. Steam Heating Apparatus—Kind,
178. Three Way Cock Air Pump Exhaust
179. Wheel Covers, Engine Truck,

TENDER.

180. Tank, Capacity, Gals.,
181. Tank Braces,
182. Tank Valves,
183. Tank Hose,
184. Tank Boxes,
185. Tender Frame, Iron or Wood,
186. Tender Frame Rods,
187. Tender and Engine Draw Bar,
188. Tender Draw Bar Coupler— Automatic,
189. Tender Trucks,
190. Tender Truck Wheels, No. new,
191. Tender Springs, Make,
192. Teader Brakes,

Date put in Shop,
Date Ready for Service,

COST OF REPAIRS.

Material,
Labor,
Total,

Remarks: .....

M. P. Form 8

SHOP FOREMAN'S REPORT TO HIS SUPERIOR OF REPAIRS ON PARTICULAR ENGINES

Engine No.....

Date in..... Date out.....

NOTE.—The numbers shown on this report correspond, so far as they go, to those shown on Form 8. For all repairs made to engines where new parts are applied the letter "X" should be entered opposite the number corresponding to the part replaced; for all parts that are repaired the letter "O" should be entered opposite the number.

This report will be sent to the general foreman, who will enter the several items shown herein, on Form 8.

1		23		79	
2		24		80	
3		25		86	
4		26		87	
5		27		88	
6		28		109	
7		29		110	
8		30		111	
9		31		112	
10		32		113	
11		33		114	
12		39		115	
13		46		116	
14		67		128	
15		68		129	
17		69		130	
19		70		136	
20		71		137	
21		72			
22		73			

Remarks: .....

.....

..... Foreman.

M. P. Form 10

SHOP FOREMAN'S REPORT TO HIS SUPERIOR OF REPAIRS ON PARTICULAR ENGINES

Engine No.....

Date in..... Date out.....

NOTE.—The numbers shown on this report correspond, so far as they go, to those shown on Form 8. For all repairs made to engines where new parts are applied the letter "X" should be entered opposite the number corresponding to the part replaced; for all parts that are repaired the letter "O" should be entered opposite the number.

This report will be sent to the general foreman, who will enter the several items shown herein, on Form 8.

16	62	94	125	151
26	63	95	126	152
34	64	96	127	156
35	65	97	131	157
40	66	98	132	158
41	74	99	133	159
42	75	100	134	160
47	76	101	135	161
48	77	102	138	162
49	78	105	139	163
51	81	107	140	165
52	82	108	141	173
53	83	117	142	174
54	84	118	143	175
55	85	119	144	176
56	89	120	145	177
57	90	121	146	178
58	91	122	147	
59	92	123	148	
60	93	124	149	

Remarks: .....

.....

..... Foreman.

M. P. Form 11

SHOP FOREMAN'S REPORT TO HIS SUPERIOR OF REPAIRS ON PARTICULAR ENGINES

Engine No.....

Date in..... Date out.....

NOTE.—The numbers shown on this report correspond, so far as they go, to those shown on Form 8. For all repairs made to engines where new parts are applied, the letter "X" should be entered opposite the number corresponding to the part replaced; for all parts that are repaired the letter "O" should be entered opposite the number.

This report will be sent to the general foreman, who will enter the several items shown herein, on Form 8.

18		154		184	
36		Beam		185	
37		155		186	
38		157		187	
43		164		188	
44		166		189	
45		167		190	
49		169		191	
50		170		192	
61		171			
103		179			
104		180			
106		181			
150		182			
153		183			

Remarks: .....

..... Foreman.

M. P. Form 12

MASTER MECHANIC'S REPORT OF COST OF REPAIRS ON PARTICULAR ENGINES

.....Shop Engine No.....

NOTE.—A report of this kind is made for each engine receiving repairs amounting to $25.00 or more. The master mechanic will enter on this report the engine number, date in shop and date out of shop, and forward it to the storekeeper in whose office the distribution of material and labor is kept, who will enter the cost of material and labor expended in the repairs and return the report to the master mechanic, who will enter the cost of repairs in the space provided in Form 8 and keep this report on file in his office.

Date in shop..... Total Cost of Material .....

Date out of Shop..... Total Cost of Labor.....

Total Cost .....

Remarks:.....

Master Mechanic.

M. P. Form 13

MASTER MECHANIC'S MONTHLY SUMMARY TO THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY IN REGARD TO HEAVY REPAIRS MADE ON ENGINES.

During the month of .....19....

NOTE.—This report is to be made by each Master Mechanic and forwarded to the Superintendent of Motive Power and Machinery by the fifteenth day of the month. It should state the nature of the work performed on each engine receiving heavy repairs at the different shops, and length of time each engine is in the shop; also, the engines that are undergoing repairs or awaiting repairs at the different shops on the division on the last day of the month.

SHOP	Engine Nos.	Date IN	Date OUT	Description of Heavy Repairs

ENGINES OUT OF SERVICE ON THE LAST DAY OF THE MONTH.

SHOP	Numbers of Engines Undergoing Repairs	Numbers of Engines Awaiting Repairs	SHOP	Numbers of Engines Undergoing Repairs	Numbers of Engines Awaiting Repairs	SHOP	Numbers of Engines Undergoing Repairs	Numbers of Engines Awaiting Repairs

M. P. Form 14

FOREMAN'S WEEKLY REPORT OF LOCOMOTIVES IN SHOP.

For the week commencing.....19....

NOTE.—This report is compiled at the general shops on Monday of each week by the general foreman and a copy sent to each shop foreman, and to the Superintendent of Motive Power and Machinery. It shows the several shops through which an engine passes from the time of arrival on the hospital track until such engine has undergone repairs and left the shops.

The first section of this report represents the gangs into which the force of the erecting shop is divided. Under each gang should be shown the number and class of each engine undergoing repairs, also the division on which it was last in service, the date in shop, date expected out and the nature of the repairs to be given. In the "Miscellaneous" column of this section should be shown the dates on which engines will be out of the shops that have been delayed beyond, or that will be out previous to their scheduled dates.

The second section shows the output or the number of engines that have left the shop during the month, the number sent out each week being added to those previously reported for the same month.

The third section shows the engines receiving boiler-shop repairs in connection with other repairs, and also the output of engines from the boiler-shop during the month. The class of repairs given an engine in the boiler-shop should be indicated by the letters as shown in the note at the left of this section.

The fourth section shows the engines that will be limbered up and put in service the coming week, and also those put in service the previous week, the number and class of the engine, and the division on which it was last in service.

The fifth section shows the number and class of all engines on the hospital track awaiting repairs, the division on which each engine was last in service, the date received on hospital track and the nature of the repairs needed.

ENGINES IN THE SHOP.

GANG I						GANG II						GANG III						GANG IV						GANG V						MISCELLANEOUS		
Engine No.	Class	Division	Date in	Date out	Repairs	Engine No.	Class	Division	Date in	Date out	Repairs	Engine No.	Class	Division	Date in	Date out	Repairs	Engine No.	Class	Division	Date in	Date out	Repairs	Engine No.	Class	Division	Date in	Date out	Repairs	Engine No.	DATE Will be Out	DATE Scheduled

OUTPUT OF THE SHOP FOR MONTH OF.....UP TO .....

GANG I						GANG II						GANG III						GANG IV						GANG V					
Engine No.	Class	Division	Date in	Date out	Repairs	Engine No.	Class	Division	Date in	Date out	Repairs	Engine No.	Class	Division	Date in	Date out	Repairs	Engine No.	Class	Division	Date in	Date out	Repairs	Engine No.	Class	Division	Date in	Date out	Repairs

ENGINES IN THE BOILER SHOP

OUTPUT OF THE BOILER SHOP FOR THE MONTH OF.....UP TO .....

NOTE—The following letters represent boiler repairs.	Eng. No.	Date in	Date Out	Repairs	Eng. No.	Date in	Date Out	Repairs	Eng. No.	Date in	Date out	Repairs	Eng. No.	Date in	Date out	Repairs	Eng. No.	Date in	Date out	Repairs
A Fire Box																				
B Half Sides																				
C Back Fire Sheet																				
D Front Fire Sheet																				
E Door Sheet																				
F Crown Sheet																				
G Smoke Arch																				
H Wagon Top																				
I Dome																				
J Back Head																				
K Extension																				
L New Boiler																				

ENGINES TO BE LIMBERED UP

Engine No.	
Class	
Division	

ENGINES PUT IN SERVICE LAST WEEK

ENGINES ON HOSPITAL TRACK

Engine No.	
Class	
Division	
Date on Track	
Repairs	

Engine No.	
Class	
Division	
Date on Track	
Repairs	

.....*General Foreman.*

M. P. Form 15

DEFINITION OF WHAT CONSTITUTES ENGINE FAILURES

1. All delays occasioned by waiting for an engine at an initial terminal, except in cases where an engine must be turned, or does not arrive at initial point in time to be cared for and dispatched before leaving time.

2. All delays on account of engine breaking down; running hot; not steaming well or having to reduce tonnage on account of defective engine; causing a delay at a terminal; or meeting point; or junction connection; or delaying traffic.

DELAYS FROM THE FOLLOWING CAUSES ARE NOT TO BE CONSIDERED AS ENGINE FAILURES.

1. Whenever engines lose time and afterwards regain it without delay to connections or other traffic.

2. Whenever a passenger or scheduled freight train is delayed from other causes, and an engine (having a defect) makes up more time than it loses on its own account.

3. Delays to passenger trains when they are less than five minutes late at terminals or junction points.

4. Delays to scheduled freight trains when they are less than twenty minutes late at terminals or junction points.

5. Delays when an engine is given excess of tonnage and stalls on a hill, providing the engine is working and steaming well.

6. Delays on extra dead freight trains if the run is made in less hours than the miles divided by ten.

7. Whenever engines are steaming poorly, or flues leaking, on any run where the engine has been delayed on side tracks other than by defects of engine, or are on the road an unreasonable length of time: say fifteen hours or more per one hundred miles.

8. For reasonable delays in cleaning fires and ash-pans on the road.

9. When engines are coming from outside points to the shop for repairs.

10. Failure to provide a particular engine which is held in the roundhouse for needed repairs, and is called for by the Operating Department, before the stated time, of which latter the Operating Department has been informed.

11. Broken draft rigging on engines and tenders caused by air being set on train, account of bursted hose or breaking in two.

12. Delays to fast schedule trains when the weather conditions are such that it is impossible to make the time, providing the engine is working and steaming well.

13. Delays when an engine gets out of coal and water, caused by being held between coal and water stations an unreasonable length of time.

M. P. Form 16

TRAIN DISPATCHER'S DAILY REPORT OF ENGINE FAILURES

.....Division. Date .....19....

NOTE.—The Train Dispatcher will make four copies of this report, daily, and send one copy to each of the following officials: the General Superintendent, Division Superintendent, Superintendent of Motive Power and Machinery and Master Mechanic. The cause and particulars of delay as given in this report must be compared with Form 17.

Should the Master Mechanic consider an engine failure has been unjustly charged he will write to the Division Superintendent stating his reasons and send a copy of his letter to the Superintendent of Motive Power and Machinery. If, upon investigation, the Superintendent finds the failure has been unjustly charged, he will cancel same using this blank for that purpose, noting "cancelled" in the Remarks column, and send a copy of the cancellaton report to the General Superintendent, Superintedent of Motive Power and Machinery and Master Mechanic.

Train No.	Conductor	Engineer	Engine No.	Cause	Time of Delay	REMARKS

M. P. Form 17

ENGINEER'S REPORT TO MASTER MECHANIC OF DELAYS ON EACH TRIP

.....Division. Engine No.....Train No.....

Date.....19..... Departed from.....at.....M.

Arrived at..... .....at.....M.

NOTE.—This report is to be made by engineers, at the end of each trip in which delays of three minutes or more occur. The cause and full particulars of all such delays must be given.

The report must be forwarded immediately to the master mechanic, who will compare it with Form 16, and investigate all discrepancies.

Whenever there is a delay in leaving or arriving at terminals, the exact time, in minutes, is to be shown, in order that the master mechanic may know how late a train is in leaving starting point or arriving at terminal without having to refer to the time card.

PLCAE DELAYED	TIME DELAYED	CAUSE OF DELAY	TIME MADE UP	
			To Station	Minutes

M. P. Form 18

MASTER MECHANIC'S TEN DAYS REPORT TO THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF ENGINE FAILURES.

On.....Division. For the ten days ending ..... 19....

NOTE.—A report of this form must be made by master mechanics, at the end of every ten days, and forwarded to the Superintendent of Motive Power and Machinery not later than three days after the termination of the period which it covers.

The first report should include all failures from the first to the tenth day inclusive; the second, from the eleventh to the twentieth day inclusive; and the third, from the twenty-first to and including the last day of the month.

It is important that the exact cause of failure be stated in each case.

Date of Failure	Engine Number	Train Number	Engineer	Total Time Delayed	Time Made Up	Cause of Failure

MONTHLY RECORD OF THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF PARTICULARS (CAUSE) OF ENGINE FAILURES ON EACH DAY OF THE MONTH

MONTH OF.....19.....

.....DIVISION

NOTE.—A summary of this form (for each division), is compiled in the office of the Superintendent of Motive Power and Machinery. It is written up daily from Form 16, and is compared with Form 18, all discrepancies being immediately investigated. The cause of the failure is entered in the proper column, and the numbers of the engines failing from such causes being entered in the proper date column opposite.

CAUSE OF FAILURE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTAL

M. P. Form 20

MONTHLY SUMMARY OF THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF CAUSE OF ENGINE FAILURES ON EACH DIVISION.

For the month of..... .....19.....

NOTE.—This monthly exhibit is compiled in the office of the Superintendent of Motive Power and Machinery on the twentieth day of the month succeeding that for which it is made. It is a summary of engine failures, and shows the number of failures from each cause on each division and for the whole road.

In order that comparison may be made, the total number of failures, and miles run per engine failure is shown for the previous month and for the corresponding month of the previous year.

CAUSE OF FAILURE.	DIVISIONS					TOTALS
HOT BEARINGS.						
1. Driving Boxes.						
2. Pins						
3. Engine Trucks,						
4. Tender Trucks						
5. Eccentrics						
6. Wedges Stuck						
7. Trailing Wheel Boxes						
MACHINERY FAILURES.						
8. Broken Piston Rods						
9. " " Head						
10. " " Glands						
11. " " Followers						
12. " " Follower Bolts						
13. Pistons, Loose						
14. " Bent						
15. Follower Bolts Loose						
16. Broken Valve Stems						
17. " Valve Stem Glands						
18. " " Yokes						
19. " " Seats						
20. Balance Plates Loose						
21. Broken Packing Rings						
22. " Cross Heads						
23. " Cross Head Keys						
24. " Cylinder Heads						
25. " Cylinder Head Studs						
26. " Cylinder Saddles						
27. " Eccentrics						
28. " Eccentric Straps						
29. " " Blades						
30. " " Bolts						
31. " " Strap Bolts						
32. Eccentric Blades Loose						
33. Eccentrics Slipped						
34. Broken Frames						
35. " Pedestal Bolts						
36. " Main Rods						
37. " Side Rods						
38. " Crank Pins						
39. " Rod Straps						
40. " Rod Bolts						
41. Main Rods Bent						
42. Rod Key Lost						
43. Rod Oil Cup Lost						
44. Broken Guides						
45. " Guide Yokes						
46. " Guide Yoke Bolts						
47. " Rocker Arms						
48. Rocker Arm Bolts Lost						
49. Broken Equalizers						
50. " Equalizer Bolts						
51. " Links						
52. " Link Blocks						
53. " Link Block Pins						
54. " Link Lifters						
55. " Driving Wheels						
56. " Driving Axles						
57. " Engine Truck Axles						
58. " Tender Truck Axles						
59. " Tender Trucks						
60. " Tender Truck Brasses						
61. " Tires						
62. Tires Loose						
63. Cellar Bolts Lost						

CAUSE OF FAILURE.	DIVISIONS					TOTALS
64. Broken Driving Boxes						
65. " Wedge Bolts						
66. " Driving Springs						
67. " Engine Truck Springs						
68. " Tender Truck Springs						
69. " Spring Hangers						
70. " Reverse Levers						
71. " Reverse Lever Latches						
BOILER FAILURES.						
72. Leaking Flues						
73. " Fire Boxes						
74. " Arch Tubes						
75. " Steam Pipes						
76. " Exhaust Pipes						
77. " Hand Hole Plates						
78. Flues Burst						
79. Arch Tubes Burst						
80. Hand Hole Plates Blown Out						
81. Stay Bolts "						
82. Fire Box Studs " "						
83. Flue Plugs " "						
84. Blow-off Cock Stuck						
85. Blow-off Cock Leaking						
86. Broken Blow-off Cock Pipes						
87. Foaming						
88. Injectors Not Working						
89. Injector Checks Stuck						
90. Broken Injector Pipes						
91. Broken Whistles						
92. Throttles Disconnected						
93. Throttles Leaking						
AIR BRAKE FAILURES						
94. Air Pumps						
95. Broken Air Pipes						
96. Broken Air Hose						
97. Air Pipes Loose						
98. Air Pipes Leaking						
99. Broken Brake Beams						
100. " Brake Rods						
101. " Driver Brake Hangers						
102. " Driver Brakes						
103. Driver Brakes Sticking						
MISCELLANEOUS FAILURES.						
104. Broken Drop Grates						
105. Grates Burned						
106. " Down						
107. " Disconnected						
108. " Stuck						
109. Broken Lubricator Glasses						
110. " Water Glasses						
111. " Tender Truss Rods						
112. " Tender Draw Heads, F.						
113. " Tender Draw Heads, B.						
114. " Engine Draw Heads, F						
115. " Steam Heat Pipes						
116. Diaphragm Down						
117. Fire Brick Arch Down.						
118. Poor Coal						
119. Not Steaming (Other Causes)						
120. Steam Hose						
121. Lubricator						
122. Packing Blowing						
123. Petticoat Pipes Misplaced						
124. Blower Pipes B'k'n or Discn'd						
125. Tank Hose Disconnected						
TOTAL NUMBER OF FAILURES						
TOTAL NUMBER OF FAILURES....19..						
TOTAL NUMBER OF FAILURES....19..						

RECAPITULATION

DIVISIONS											All Divisions
NUMBER OF FAILURES											
TOTAL ENGINE MILES											
MILES RUN PER ENGINE FAILURE											
MILES RUN PER ENGINE FAILURE.....19..											
MILES RUN PER ENGINE FAILURE. ... 19..											

M. P. Form 21.

LOCOMOTIVE ENGINEER'S TRIP REPORT OF TIME WORKED.

Month of ..... 19....

NOTE.—At the close of each day's service or trip, engineers will make a detailed report on this form and forward it to the roundhouse foreman, who will examine same and forward it to the timekeeper.

Mileage made with light engines should be indicated by the letter "L"; with dead engine, hauled in train, by letter "D."

ENGINE NO.	TRAIN NO.	TIME CALLED FOR	DEPARTED		ARRIVED		MILES RUN AS PER TIME TABLE				HOURS WORKED IN ADDITION TO MILES RUN (Particulars must be given on back of this Report)				NAME OF FIREMAN
			Time	From	At	Time	Pass.	Frt.	Gravel	W. Frt.	Work Train	Switching	Over Time	Delayed Time	
		.....	.....Day			.....Day									
		M	M			M									
		.....	.....Day			.....Day									
		M	M			M									
		.....	.....Day			.....Day									
		M	M			M									
		...	.....Day			.....Day									
		M	M			M									

.....Conductor

.....Engineer

M. P. Form 22.

TRAIN DISPATCHER'S DAILY RECORD OF TRAIN MOVEMENTS.

.....DIVISION.

Date..... 19....

NOTE—The train dispatcher will enter hereon a record, daily, of train movements on his division and forward a copy to the engineers' and firemen's timekeeper. Entries for continuous trips should be made in succession.

Direction	Train No.	Engine No.	Engineers	Conductors	DEPARTING			ARRIVING		Actual Mileage	Hours on Duty	TONNAGE		Class Service	Remarks
					Terminal	Time Ordered	Time Left	Terminal	Time			Capacity Engine	Hauled by Engine		

.....

Chief Train Dispatcher.

M. P. Form 23

ENGINEER'S REPORT OF SWITCHING TIME.

NOTE.—When an engine crew is engaged in switching, a report of this character must be made by the engineer at the close of the day's service and forwarded to the agent (or person in charge at the point where the work was performed), who, after approving same, will forward it to the timekeeper. If time is taken for meal, one hour should be deducted in allowing the time as shown by this report.

	REMARKS. Did you work noon hour?
No. of Hours..... Engine No. { ..... /	
Switching at.....	
From.....o'clock.....M. To.....o'clock.....M.	
Date.....19.....	
....	
Engineer. *Fireman.*	

M. P. Form 24

AGENT'S REPORT OF TIME WORKED BY SWITCH YARD CREWS.

At.....for 24 hours ending .....o'clock....M.....19....

Signed .....

INSTRUCTIONS:—This report is to be made in triplicate (by the use of carbon sheets) by the agent, yard master or other person in charge of the station or yard where switching crews are engaged.

A copy should be sent daily to the Division Superintendent and Storekeeper, and a copy retained as a record by the maker.

TIME WORKED BY ENGINEMEN.

Engine No.	Name of Engineer	Name of Fireman	Time Commenced Work	Time Quit Work	Time Taken for Meals	Total Hours Worked

TIME WORKED BY TRAINMEN.

Engine No.	Name of Foreman	Name of Helpers	Time Commenced Work	Time Quit Work	Time Taken for Meals	Total Hours Worked

M. P. Form 25

ENGINEER'S MONTHLY REPORT OF TIME WORKED.

.....Engineer.

For the month of.....19.... .....Division.

NOTE.—This report is made by each engineer and forwarded to the time-keeper not later than the second day after the close of the month.

Miscellaneous time is intended to include time attending law suits inquests, dispatching, watching and trying engines, or other time not actually on road or engaged in switching services.

Delayed and overtime should be entered with running time.

NAME OF FIREMAN	Date	Engine Number	Miscellaneous Time	Switching Time	RUNNING TIME				
					Way-Frt. Eng.		Other Engines		
					Stand.	Large	Stand.	Large	
	1								
	2								
	3								
	4								
	5								
	6								
	7								
	8								
	9								
	10								
	11								
	12								
	13								
	14								
	15								
	16								
	17								
	18								
	19								
	20								
	21								
	22								
	23								
	24								
	25								
	26								
	27								
	28								
	29								
	30								
	31								
TOTALS.									

Send Pay Check to.....

DIVISION TIME BOOK OF LOCOMOTIVE ENGINEERS, GIVING PARTICULARS OF THE SERVICE OF EACH.

Page.....

Month of..... 19.... .....Engineer.

Number of miles run must be based on distances as shown by Time Table.

Name of Fireman	Date	Train No.	Miscell'n's Time	Switching Time	Running Time: Way Freight Eng. Class of Engine / Rate of Pay	Running Time: Frt. and Construct'n Class of Engine / Rate of Pay	Running Time: Passenger Class of Engine / Rate of Pay	Engine No.	From	To	Miles Run on ..... Div.: Pass.	Freight	Work	Switch	Miles Run on ..... Div.: Pass.	Freight	Work	Switch	Miles Run on ..... Div.: Pass.	Freight	Work	Switch	Delayed Time	Overtime	Constr'tive Mil'ge	Remarks
Short in previous month																								
	1																							
	2																							
	3																							
	4																							
	5																							
	6																							
	31																							
Total					...¢	...¢	...¢	...¢	...¢	...¢	...¢	...¢	...¢	...¢	...¢	...¢	...¢	...¢	...¢	...¢	...¢	...¢				

Description of Service	No. of Hrs. Allowed	Rate Per Hour	Amount
Road Service,		*Cents*	
Road Service,		"	
Road Service.		"	
Road Service,		"	
Pusher Service.		"	
Switching,		"	
Dispatching,		"	
Total,		"	

ENGINEHOUSE REGISTER.

Enginehouse,.....19..

DEPARTURES. (OR ARRIVALS.)

Number of Train	Number of Engine	Kind of Train	Destination	Engineer	Fireman	Time of Departures

NOTE—The page opposite this in the register is the same form as the above, and is used for "*Arrivals.*" This book is useful for reference in keeping the switching time of engineers and firemen.

M. P. Form 28

STOREKEEPER'S MONTHLY REPORT TO THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF DELAYED AND OVER TIME ALLOWED ENGINEERS AND FIREMEN

On.....Division for the month of.....19....

Engineman	Date	Engine Number	Train Number	HOURS OF OVERTIME: Way Freight in Excess of Schedule Time	HOURS OF OVERTIME: Way Freight as per Time Card	HOURS OF OVERTIME: On Through and Special Trains	HOURS OF OVERTIME: ENGINEER'S RATE PER HOUR	HOURS OF OVERTIME: FIREMAN'S RATE PER HOUR	Where Delayed	HOURS OF DELAYED TIME: ENGINEER'S RATE PER HOUR	HOURS OF DELAYED TIME: FIREMAN'S RATE PER HOUR	HOURS OF DEADHEAD TIME: Engin'r's Rate per Hour	HOURS OF DEADHEAD TIME: Fireman's Rate per Hour	CAUSE OF DELAY

M. P. Form 29

MONTHLY RECORD OF THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF THE GROSS COST OF DELAYED AND OVERTIME ON EACH DIVISION.

For the month of.....19....

NOTE—This summary is compiled in the office of the Superintendent of Motive Power and Machinery from Form 28, copies being sent to the officials interested on the tenth day of the month.

Divisions	Delayed Time	Overtime			Constructive Mileage	Dead Heading	Total Cost
		Way-Freight in Excess of Schedule Time	Way-Freight as per Time Card	On Through and Special Trains			

NUMBER OF HOURS AND COST OF DELAYED AND OVERTIME ONLY.

Divisions	No. of Hours of Delayed Time	No. of Hours of Overtime.			Total Cost
		Way-Frt. in Excess of Schedule or Mileage	Way-Frt. as per Time Card	On Through or Special Trains	

MONTHLY STATEMENT OF LOCOMOTIVE MILEAGE ON EACH DIVISION.

On.....Division. During the month of.....19....

NOTE.—This record is compiled monthly by division time-keeper from Form 26, and shows the mileage made by each engine in the different classes of service. The engine numbers should be entered in numerical order in the place provided, the page in the time book from which the entry is taken should be shown and the mileage entered in the column corresponding to the class of service in which the engine was engaged.

The several entries for each engine should be footed, and the total mileage made by all engines, balanced by services, with the total mileage shown on Form 26, which should also be summarized on a form of this character.

The statement should be retained by the time keeper as an office record.

Page No. of Time Book	SERVICE				Page No. of Time Book	SERVICE				Page No. of Time Book	SERVICE				Page No. of Time Book	SERVICE			
	Passenger	Freight	Work	Switch		Passenger	Freight	Work	Switch		Passenger	Freight	Work	Switch		Passenger	Freight	Work	Switch
	ENGINE NO.....					ENGINE NO.....					ENGINE NO.....					ENGINE NO			

M. P. Form 31

MONTHLY REPORT OF LOCOMOTIVE MILEAGE (CLASSIFIED) OF EACH ENGINE.

.....Division. During the month of.....19.....

NOTE.—This report should be made by division storekeepers (or timekeepers), and forwarded to the general storekeeper on or before the twelfth day of each month. It should show the total number of miles made in the different classes of service by each engine on the division as shown by Form 30.

Before forwarding the report, the storekeeper must verify it by comparing same with the total mileage as shown by Form 26.

Engine No.	Pass.	Frt.	Work	Switch	Engine No.	Pass.	Frt.	Work	Switch

MONTHLY RECORD OF THE MILEAGE OF EACH ENGINE.

NOTE.—The information called for here is entered each month by the general storekeeper. Three engine numbers are included on each page and the mileage is entered according to the class of service, under each engine number, as shown on Form 31. The name of the division on which each engine is engaged must be shown and in case an engine is engaged on two or more divisions in one month, the mileage made on each division should show hereon and a total footing made.

The name of the month should be stamped in the line below the last entry or total footing for the previous month.

ENGINE NO.					ENGINE NO.					ENGINE NO.				
DIV.	SERVICE				DIV.	SERVICE				DIV.	SERVICE			
	Pass.	Frt.	Work	Swi.		Pass.	Frt.	Work	Swi.		Pass.	Frt.	Work	Swi.

M. P. Form 33

MONTHLY REPORT OF PARTICULARS OF COST OF REPAIRS OF EACH LOCOMOTIVE.

At.....Shops. During the month of.....19....

NOTE.—This report made by storekeepers should include repairs made to locomotives at their shops.

Engine numbers must be entered in numerical order, and the amount of material and labor expended in repairs entered opposite the number of the engine.

The report must be footed and balanced with the amount charged to repairs of locomotives in the material and labor distribution books. An impression must be taken of the report, after which it will be forwarded to the general storekeeper, on or before the fourteenth day of each month.

Eng. No.	Material	Labor	Eng No.	Material	Labor	Eng. No.	Material	Labor

M. P. Form 34

MONTHLY RECORD OF REPAIRS ON EACH LOCOMOTIVE.

During the month of.....19.....

NOTE.—This information is compiled monthly in the office of the general storekeeper from Form 33.

The numbers of the engines are entered in numerical order, and the cost of material and labor expended in repairs (as shown on Form 33), entered opposite.

Three columns are provided each for entries of material and labor, and in case the same engine number appears on more than three different reports (Form 33), two entries may be made in each column opposite the engine number.

The amounts should be cross-footed into the total columns; these amounts should then be entered on Form 35, for the division to which the engine is assigned as per the name of the division entered in the space provided hereon.

Engine No.	Material			Total	Labor			Total	Division

M. P. Form 35

MONTHLY REPORT FOR THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF THE MILES RUN AND COST OF REPAIRS OF EACH ENGINE.

For the month of.....19.....

.....Division.

NOTE.—This report is compiled in the office of the general storekeeper and sent to the Superintendent of Motive Power and Machinery on the twenty-sixth day of each month.

A separate report should be made for each division. It should show, in numerical order, the numbers of the engines that are assigned to that division; the total mileage made by each engine in the different classes of service during the month, as shown on Form 32, and the cost of material and labor expended in the repairs of each engine, as shown on Form 34.

Number of Engine	No. Miles run on Passenger Trains	No. Miles run on Frt. Trains	No. Miles run on Work Trains	No. Miles Switching	Total Miles Run	Cost of Repairs			Remarks
						Material	Labor	Total	

M. P. Form 36.

MONTHLY REPORT FOR DIVISION MASTER MECHANIC OF MILEAGE AND COST OF REPAIRS OF EACH LOCOMOTIVE ON HIS DIVISION.

.....Division. During the month of.....19....

NOTE.—This summary is compiled in the office of the general storekeeper and shows the engine number, total mileage and total cost of repairs as recapitulated from Form 35. It must be footed and balanced with the totals. as shown on Form 35, and a copy forwarded to the master mechanic, on the twenty-sixth day of the month.

In case a portion of the cost of repairs of an engine is chargeable to another division a statement to that effect should be made in the "Remarks" column.

Engine Number	Mileage	Cost of Repairs	REMARKS	Engine Number	Mileage	Cost of Repairs	REMARKS

M. P. Form 37

RECORD OF MILEAGE (CLASSIFIED) AND COST OF REPAIRS OF EACH LOCOMOTIVE.

NOTE.—This record book is written up by the general storekeeper. The number of the page corresponds to the engine number.

The name of the division to which the engine is assigned, the mileage made in the different classes of service, and the amount of material and labor expended in the repairs as shown on Form 35 is entered each month.

Mileage made by an engine on divisions other than the one to which it is assigned, should be entered in the space provided, giving the name of the division in each case.

ENGINE NO.....

	MILEAGE						COST OF REPAIRS			MILEAGE ON OTHER DIVISIONS					
	Div.	Pass.	Frt.	Work	Switch.	Total	Material	Labor	Total	Div.	Pass	Frt.	Work	Switch.	Tot'l
July															
August															
September															
October															
November															
December															
January															
February															
March															
April															
May															
June															

FORM OF COAL TICKETS USED ON ENGINES.

NOTE—When coal is delivered to a locomotive, the engineer is required to give a ticket of this character for each ton received. Tickets should be given in numerical order, and of the class of service in which the engine is engaged.

ONE TON COAL DELIVERED TO PASSENGER LOCOMOTIVE ..... Division 3	ONE TON COAL DELIVERED TO FREIGHT LOCOMOTIVE ..... Division 3	ONE TON COAL DELIVERED TO SWITCHING LOCOMOTIVE ..... Division 3
ONE TON COAL DELIVERED TO PASSENGER LOCOMOTIVE ..... Division 2	ONE TON COAL DELIVERED TO FREIGHT LOCOMOTIVE ..... Division 2	ONE TON COAL DELIVERED TO SWITCHING LOCOMOTIVE ..... Division 2
ONE TON COAL DELIVERED TO PASSENGER LOCOMOTIVE ..... Division 1	ONE TON COAL DELIVERED TO FREIGHT LOCOMOTIVE ..... Division 1	ONE TON COAL DELIVERED TO SWITCHING LOCOMOTIVE ..... Division 1
ONE TON COAL DELIVERED TO PASSENGER LOCOMOTIVE ..... Division 0	ONE TON COAL DELIVERED TO FREIGHT LOCOMOTIVE ..... Division 0	ONE TON COAL DELIVERED TO SWITCHING LOCOMOTIVE ..... Division 0

NOTE—Upon some roads the number of the engine is printed on the ticket, the account being kept directly with the engine.

M. P. Form 39

MONTHLY REPORT OF FUEL DELIVERED AT EACH POINT TO LOCOMOTIVES.

Daily record of Fuel delivered to.....Division Locomotives

At.....Station, during the month of.....19....

NOTE.—Fuel tickets (in one ton or one cord quantities) are provided engineers for use as required. Agents and others in charge of fuel stations must collect tickets for all fuel delivered to locomotives. When collected they must be put in a box, which must be securely locked. Care must be exercised to see that the tickets received correspond with the fuel delivered. Also that the name of the division to which the engine is assigned is legible. In the event an engineer should refuse or neglect to deliver tickets for fuel received by him, report thereof must be made, forthwith, to the Division Master Mechanic, who will investigate the case and see that tickets are forwarded in accordance with the facts.

A report (of this form) is to be made for each division. The quantities, as per tickets. are to be entered on this report daily. At the close of the month it will be footed and an impression taken of it, after which it will be forwarded to the Storekeeper for the division, as may be directed. The tickets for fuel collected during the month must be arranged according to the order of service, viz: a—Passenger; b—Freight; c—Work, Switching, etc.

The tickets are colored red, white and blue (in the above order), so as to be easily distinguished. Before sending these tickets to headquarters, they must be arranged according to service, viz.: Passenger, Freight, etc.; also according to divisions; the packages for each class of service for each division being tied securely together.

It is the duty of the Agent or Storekeeper in charge of a fuel supply depot to see that those in immediate charge understand their duties and that they observe them. Fuel in store or in transit must be carefully guarded, and in the event of a shortage investigation must at once be set on foot and the proper official notified.

DATE	PASSENGER SERVICE.		FREIGHT SERVICE		WORK AND SWITCHING SERVICE		TOTAL	
	Tons Coal	Cords Wood	Tons Coal	Cords Wood	Tons Coal	Cords Wood	Tons Coal	Cords Wood
1								
2								
3								
4								
5								
6								
7								
8								
and so on to 31								

.....AGENT.

M. P. Form 40

MONTHLY SUMMARY OF FUEL DELIVERED TO LOCOMOTIVES.

Assigned to.....Division during the month of .....19.....

NOTE.—This record is compiled by division storekeepers from Form 39. A separate statement must be made for the locomotives of each division to which fuel has been delivered Reports must be footed and balanced and an impression taken, and sent forward to the general stoorekeeper on the fifth day after the close of the month. Before forwarding the statement the storekeeper must verify it by the tickets actually delivered by locomotive engineers.

When locomotives make mileage on two or more divisions, the amount of fuel to be charged to each division will be apportioned by the general storekeeper.

STATIONS	PASS. SERVICE		FRT. SERVICE		WRK. AND SWITCH. SERVICE		TOTAL	
	Tons Coal	Cords Wood	Tons Coal	Cords Wood	Tons Coal	Cords Wood	Tons Coal	Cords Wood

.....*Storekeeper.*

FORM OF OIL AND WASTE TICKETS USED ON ENGINES.

NOTE.—When oil or waste is delivered to an engineer he will give a ticket of this character for the number of pints of oil or pounds of waste received.

Tickets should be given in numerical order, and correspond to the kind of oil or waste received.

The engine number, class of service and date should be entered on each ticket by the engineer, before being given to the person delivering the oil or waste.

4 PINTS ENGINE OIL DELIVERED

TO ENG. ..... IN

..... SERVICE

DATE ..... 19....

..... ENGINEER

4 PINTS VALVE OIL DELIVERED

TO ENG. ..... IN

..... SERVICE

DATE ..... 19....

..... ENGINEER

4 PINTS SIGNAL OIL DELIVERED

TO ENG. ..... IN

..... SERVICE

DATE ..... 19....

..... ENGINEER

4 PTS. CAR OIL DELIVERED

TO ENG. ..... IN

..... SERVICE

DATE ..... 19....

..... ENGINEER

1/2 POUND COTTON WASTE DELIVERED

TO ENG. ..... IN

..... SERVICE

DATE ..... 19....

..... ENGINEER

1/2 POUND WOOL WASTE DELIVERED

TO ENG. ..... IN

..... SERVICE

DATE ..... IN

..... ENGINEER

M. P. Form 42

MONTHLY REPORT OF TOTAL AMOUNT OF OIL AND WASTE DELIVERED TO LOCOMOTIVES ON EACH DIVISION.

At..... During the month of.....19.....

NOTE.—This report is compiled by all disbursing storekeepers, and should be forwarded to the general storekeeper (after being copied), on or before the tenth day of each month. It should show the number of pints of each kind of oil, and pounds of waste delivered to locomotives on each division.

Pints of Oil	Division	Division	Division	Division	Division	Division
Engine						
Kerosene						
Signal						
Cylinder						
Car						
Total						
Pounds of Waste						
Cotton						
Wool						

M. P. Form 43

ROUNDHOUSE FOREMAN'S MONTHLY REPORT OF ENGINES WIPED DAILY.

At .....Round House. During the month of.....19....

.....Division.

NOTE.—This report is made by all round-house foremen at the end of each month to the local storekeeper. It should show the number of engines in each service that are wiped daily, the number wiped by the day force being be shown separately from those wiped by the night force.
A separate report must be made for the engines of each division.

NUMBER OF ENGINES WIPED.

Date	Passenger		Freight		Work		Switching		Remarks
	Day	Night	Day	Night	Day	Night	Day	Night	
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
Total									

M. P. Form 44

MONTHLY SUMMARY OF CHARGES TO VARIOUS OPERATING ACCOUNTS FOR MATERIAL AND LABOR ACCOUNT OF ENGINES ON EACH DIVISION.

At..... For the month of.....19..

NOTE.—This report is to be compiled by all storekeepers who keep distribution books. It should be forwarded to the general storekeeper (after being copied), on or before the twelfth day of each month.

Under the heading "Fuel Delivered to Locomotives," should be reported the number of tons of coal and cords of wood delivered to locomotives in the different classes of service, and showing the quantity chargeable to each division. These figures are compiled from Form 40, and any charges or credits shown in the material distribution book, on account of fuel furnished to locomotives in joint service, should be added to or subtracted from the fuel as shown on this report.

Charges to the accounts "Engineers and Firemen," "Oil, Waste and Tallow used on Locomotives," "Locomotive Wipers and Dispatchers," "Round House Laborers" and "Locomotive Supplies," should be reported in the spaces provided, and should show the amounts chargeable to each division on account of the different classes of service. The total of each account should agree with the amount charged such account in the material and labor distribution books before deducting the credits on account of work train invoices.

FUEL DELIVERED TO LOCOMOTIVES

DIVISIONS	Passenger		Freight		Work and Switching		TOTAL	
	Tons Coal	Cords Wood	Tons Coal	Cords Wood	Tons Coal	Cords Wood	Tons Coal	Cords Wood
TOTAL								

OIL, WASTE AND TALLOW USED ON LOCOMOTIVES.

DIVISIONS	Passenger		Freight		Work and Switching		TOTAL	
	Material	Labor	Material	Labor	Material	Labor	Material	Labor
TOTAL								

ENGINEERS AND FIREMEN.

DIVISIONS	Passenger		Freight		Work and Switching		TOTAL	
	Material	Labor	Material	Labor	Material	Labor	Material	Labor
TOTAL								

LOCOMOTIVE WIPERS AND DISPATCHERS.

DIVISIONS	Passenger		Freight		Work and Switching		TOTAL	
	Material	Labor	Material	Labor	Material	Labor	Material	Labor
TOTAL								

ROUND HOUSE LABORERS.

DIVISIONS	Passenger		Freight		Work and Switching		TOTAL	
	Material	Labor	Material	Labor	Material	Labor	Material	Labor
TOTAL								

LOCOMOTIVE SUPPLIES.

DIVISIONS	Passenger		Freight		Work and Switching		TOTAL	
	Material	Labor	Material	Labor	Material	Labor	Material	Labor
TOTAL								

STOREKEEPER.

M. P. Form 45

LOCOMOTIVE REBORT—PARTICULARS OF SERVICE AND COST FOR REPAIRS, SUPPLIES AND LABOR.
A SUMMARY OF LOCOMOTIVE PERFORMANCES

FOR MONTH OF ..... 19...

NOTE—Division expenses include the proportion of general repairs of locomotives which have been used on two or more divisions.
Rebuilding and all other expenses appertaining to repairs are included herein.
The oil charged below includes that which is used in head lamps, and lamps of enginemen.
Locomotives engaged in hauling work trains are allowed eight miles per hour, those in switching service six miles per hour
Ton mileage includes cars and contents, but does not include engine and tender.

DIVISIONS	Year	Miles Operated	Average Number Locomotives in Service	TRAIN TONNAGE: Per Pass Eng. Mile	Per Frt. Eng. Mile	Per Frt. Train Mile	TON MILEAGE: Passenger Service	Freight Service	TOTAL	FUEL CONSUMED: Tons Coal	Cords Wood	POUNDS COAL CONSUMED PER: 1000 Pass. Ton Miles	1000 Frgt. Ton Miles
	19...												
	19...												
	19...												
	19...												
	19...												
TOTAL	19...												
	19...												

COST—PASSENGER SERVICE (In cents per 1000 Ton Miles)

DIVISIONS	Year	Fuel	Oil and Waste	Repairs	L. W. & D. & R. H. Labor	Tools and Supplies	REPAIRS: Material	Labor	TOTAL
	19...								
	19...								
	19...								
	19...								
	19...								
TOTAL	19...								
	19...								

COST—FREIGHT SERVICE (In cents per 1000 Ton Miles)

DIVISIONS	Year	Fuel	Oil and Waste	Repairs	L. W. & D. and R. H. Lbr.	Tools and Supplies	REPAIRS: Material	Labor	TOTAL
	19...								
	19...								
	19...								
	19...								
	19...								
TOTAL	19...								
	19...								

TOTAL COST OF SERVICE

DIVISIONS	Year	Fuel	Oil and Waste	Repairs	L. W. & D. & R. H. Labor	Tools and Supplies	REPAIRS: Material	Labor	TOTAL
	19...								
	19...								
	19...								
	19...								
	19...								
TOTAL	19...								
	19...								

LOCOMOTIVE MILEAGE

DIVISIONS	Year	Passeng'r Service	Freight Service	Work Service	Switching Service	Total All Service	AVERAGE PER LOCOMOTIVE: Passeng'r	Freight	Switching
	19...								
	19...								
	19...								
	19...								
	19...								
TOTAL	19...								
	19...								

CAR MILEAGE

DIVISIONS	Year	Passenger	FREIGHT: Loaded	Empty	TOTAL Freight
	19...				
	19...				
	19...				
	19...				
	19...				
TOTAL	19...				
	19...				

..... 19..... Wood was rated at $ ... per cord; Coal $ ..... per ton.
..... 19..... Wood is rated at $ ... per cord; Coal $ ..... per ton.

Total Number Locomotives

FOREMAN'S MONTHLY REPORT TO MASTER MECHANIC OF CAST-IRON TRUCK AND TENDER WHEELS APPLIED TO AND REMOVED FROM LOCOMOTIVES.

On Division..... During the month of..... 19....

NOTE.—At all points where cast iron truck and tender wheels are removed, a report of this character must be made by the foreman in charge, at the end of each month. After copying the same he should forward it to the Division Master Mechanic. The latter will make a summary (on this form), of all cast-iron truck and tender wheels removed on his division during the month, and after taking an impression of same, will forward it to the Superintendent of Motive Power and Machinery on or before the twelfth day of the following month.

Engine No.	Serial Letter and No. of Wheel	Size of Wheel	Truck or Tender Wheel	Maker's Name	Applied		Removed		Date Cast	Cause of Removal	Serial Letter and No. of Axle	Size of Axle	Remarks
					Place	Date	Place	Date					

M. P. Form 47

MONTHLY RECORD OF SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF PARTICULARS OF EACH DEFECTIVE CAST IRON ENGINE AND TENDER WHEEL REMOVED.

During the month of.....19....

Size and kind of wheels..... Manufactured by.....

NOTE.—This record is compiled in the office of the Superintendent of Motive Power and Machinery on the twenty-fifth day of each month.

It is made from Form 46, and shows all cast iron engine and tender wheels removed account being defective. A separate record is made for each size and kind of wheel manufactured by the same company. The total mileage made by each wheel is shown in the column provided.

Where Removed	Engine Number	Serial Letter and No. of Wheel	Date		Mileage	Date Cast	Cause of Removal
			Applied	Removed			

MONTHLY SUMMARY OF THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF THE GROSS NUMBER OF DEFECTIVE CAST IRON LOCOMOTIVE WHEELS REMOVED, MADE BY DIFFERENT MANUFACTURERS.

DURING THE MONTH OF.....19....

NOTE.—This record is compiled monthly, for the whole road, in the office of the Superintendent of Motive Power and Machinery.

It shows separately the total number of cast iron wheels made by different manufacturers that have been removed from locomotives during the month on account of various causes as shown herein; also average mileage per wheel and the number that are being held for exchange on account of not making their guaranteed mileage.

Maker's Name	Wheels Removed on Account of Sliding		Wheels Removed on Account of Sharp Flanges		Wheels Removed, not Includ'g Wheels Slid or Sharp Flanges		Total Number of Wheels Removed for all Causes		No. of Wheels held for Exchange not making Guarantee
	No. of Wheels	Average Mileage	No. of Wheels	Average Mileage	No. of Wheels	Average Mileage	No. of Wheels	Average Mileage	
Total,									

M. P. Form 49

MONTHLY REPORT OF THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY TO THE PURCHASING AGENT OF DEFECTIVE CAST IRON WHEELS REMOVED FROM LOCOMOTIVES AND BY WHOM MADE.

During the month of.....19....

NOTE.—This report is made by the Superintendent of Motive Power and Machinery to the Purchasing Agent.

It shows separately the total number of defective cast iron wheels manufactured by each firm, that have been removed from locomotives during the month; their average mileage; also number of wheels of each size failing to made good their guarantee.

MAKER'S NAME	Wheels Removed		Wheels Failing Under Guarantee			
	Number	Average Mileage	Number	Size	Average Mileage	Guarant'd Mileage

M. P. Form 50.

MONTHLY REPORT OF THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF WHEELS THAT HAVE FAILED TO MEET GUARANTEES OF MAKERS.

Defective wheels removed from locomotives during the month of.....19....

Manufactured by.....

NOTE.—This report is made by the Superintendent of Motive Power and Machinery to the General Storekeeper as soon after the first of the month as the locomotive mileage can be obtained. All engine truck and tender wheels failing to make their guaranteed mileage (and which have been accepted by the wheel company's inspector) should be included in this report. A bill should be made against the makers for the deficiency as agreed upon.

Serial Letter and Number	Size	Weight	Kind	DATE						MILEAGE			Cause of Removal
				CAST		APPLIED		REMOVED					
				Month	Year	Month	Year	Month	Year	Guaranteed	Actual	Deficiency	

M. P. Form 51.

RECORD OF THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF ENGINE TRUCK AND TENDER WHEELS APPLIED TO AND REMOVED FROM EACH LOCOMOTIVE.

Eng. No.	Serial Letter and No. of Wheel	Size	Engine Truck or Tender Wheels	Maker's Name	Applied		Removed		Cause of Removal	No. of Axle
					Place	Date	Place	Date		

M. P. Form 52.

SHOP FOREMAN'S MONTHLY REPORT TO THE MASTER MECHANIC OF PARTICULARS OF STEEL TIRED ENGINE TRUCK AND TENDER WHEELS APPLIED TO OR REMOVED FROM LOCOMOTIVES.

ON.....DIVISION. DURING THE MONTH OF.....19....

NOTE.—At all points where steel-tired engine truck and tender wheels are removed, a report of this character must be made, by the foreman in charge, at the end of each month. After copying same he should forward it to the Division Master Mechanic. The latter will make a summary (on this form) of all steel-tired engine truck and tender wheels removed on his division during the month, and after taking an impression of same, will forward it to the Superintendent of Motive Power and Machinery on or before the fifth day of the following month.

Serial Letter and No. of Wheel	Number of Tire	Maker's Name of		Size of Wheel	Truck or Tender Wheel	Engine Number	Applied		Removed		Cause of Removal	No. of Axle	Size of Axle	Thickness of Tire after Turning	REMARKS
		Wheel	Tire				Place	Date	Place	Date					

M. P. Form 53

INDEX TO RECORD OF STEEL-TIRED ENGINE TRUCK WHEELS.

Locomotive No..... .....

NOTE.—The information called for on this form should be entered monthly from the Master Mechanics' wheel reports. When wheels or tires are applied, the number of same and date applied should be entered in the spaces provided, when removed the numbers should be cancelled and the date removed, entered in the proper columns.

RECORD OF STEEL TIRES				RECORD OF CAST WHEEL CENTERS			
No. of Tire	MAKE	Date Applied	Date Remov'd	No. of Wheel	MAKE	Date Applied	Date Remov'd

M. P. Form 54

RECORD OF SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF STEEL TIRES ON ENGINE TRUCK WHEELS

No. of Tire	Maker	Thickness of Tires	Eng. No.	APPLIED		REMOVED		Mileage	Eng. No.	APPLIED		REMOVED		Mileage	Eng. No.	APPLIED		REMOVED		Mileage	Eng. No.	APPLIED		REMOVED		Mileage	Eng. No.	APPLIED		REMOVED		Mileage
				Place	Date	Place	Date			Place	Date	Place	Date			Place	Date	Place	Date			Place	Date	Place	Date			Place	Date	Place	Date	

M. P. Form 55

MONTHLY REPORT TO THE SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF ENGINE DRIVING WHEEL TIRES APPLIED AND REMOVED.

At.....Shop. During the month of.....19....

NOTE.—This report should be made monthly by the foreman at each shop where engine driving wheel tires are exchanged. It should be sent to the Superintendent of Motive Power and Machinery on or before the twelfth day of the following month. Special care should be taken to show the thickness of all tires when applied, removed or turned.

Engine Number	Diameter of Wheels	Make of Tire	Serial Letter and No. of Tire	DATE			Thickness of Tire	Cause of Removal
				Applied	Removed	Turned		

M. P. Form 56

INDEX TO DRIVING WHEEL TIRE RECORD.

Locomotive No.....

NOTE.—The information called for hereon should be entered each month from Form 55. When tires are applied the numbers of same, and date applied should be entered in the spaces provided; when removed, the numbers should be cancelled and the date removed entered in the proper columns.

No. of Tire	MAKE	Date Applied	Date Remov'd	No. of Tire	MAKE	Date Applied	Date Remov'd

M. P Form 57

RECORD OF SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF DRIVING WHEEL TIRES

No. of Tire	Maker	Inside Diam. of Tire	Thickness of Tire	Engine No.	Applied	Rem'v'd	Mileage	Thickness After Turning	Engine No.	Applied	Rem'v'd	Mileage	Thickness After Turning	Engine No.	Applied	Rem'v'd	Mileage	Thickness After Turning	Engine No.	Applied	Rem'v'd	Mileage	Thickness After Turning	Engine No.	Applied	Rem'v'd	Mileage	Thickness After Turning	Engine No.	Applied	Rem'v'd	Mileage	Thickness After Turning	Engine No.	Applied	Rem'v'd	Mileage	Thickness After Turning
					Place / Date	Place / Date				Place / Date	Place / Date				Place / Date	Place / Date				Place / Date	Place / Date				Place / Date	Place / Date				Place / Date	Place / Date				Place / Date	Place / Date		

M. P. Form 58.

DAILY REPORT OF DISTRIBUTION OF SHOP LABOR OF EACH MAN

DATE..... 19 .

Check No..... Name.....

NOTE.—This form is to be filled out by the employe each day, giving a detailed account of the work performed by him.

It should then be approved by the foreman and forwarded by him to the timekeeper for entry in the general time book.

Hours Worked	Engine or Other Account Worked On	REMARKS

EXAMINED

FOREMAN

M. P. Form 59.

MASTER MECHANIC'S MONTHLY STATEMENT TO SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF COMPARATIVE COST OF LABOR

.....DIVISION. DETAILED STATEMENT OF PAY ROLLS. .....19.... .....19.... and.....19....

NAME OF PAY ROLL	C'rr'sp'nd'g Mo. .....19....	Current Mo. .....19....	Increase	Decrease	Cause of Increase or Decrease	Previous Mo. .....19....	Current Mo. ..... 19....	Increase	Decrease	Cause of Increase or Decrease
TOTALS.....										

M. P. Form 60

SHOP FOREMAN'S MONTHLY REPORT TO MASTER MECHANIC OF NUMBER OF MEN OF EACH CLASS OF LABOR EMPLOYED DURING THE MONTH AND WAGES PAID.

FORCE EMPLOYED IN THE LOCOMOTIVE DEPARTMENT AT .....

ON THE LAST DAY OF ..... 19.....

OCCUPATION.	Rates Per Hour	Rates Per Month	No. of Men	Total Amt Per Day	Avrg. Amt Per Day
Master Mechanics,					
General Foremen,					
Foremen,					
Draughtsmen,					
Clerks,					
Operators,					
Machinists,					
Machinists' Helpers,					
Machinists' Apprentices,					
Boiler Makers,					
Boiler Makers' Apprentices,					
Boiler Makers' Helpers,					
Blacksmiths,					
Blacksmiths' Helpers,					
Blacksmiths' Apprentices,					
Painters,					
Copper and Tinsmiths,					
Copper and Tinsmiths' Appren,					
Carpenters,					
Truck Repairers,					
Boiler Washers,					
Stationary Engineers,					
Stationary Firemen,					
Firing-up Locomotives,					
Wipers,					
Wipers at Outside Points,					
Turn-Table and Pitmen,					
Sandmen,					
Laborers and Sweepers,					
Callers,					
Switch-Tenders,					
Oilmen,					
Engine Inspectors,					
Watchmen,					
Dispatchers' Helpers,					
Pumpers,					
Telephone Boys,					
Coal-Heavers,					
Teamsters,					
Coal-Hoisters,					
Rail Mill Carriage Men,					
Rail Mill Straighteners,					
Sawyers,					
Totals,					

M. P. Form 61

MASTER MECHANIC'S MONTHLY REPORT TO SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF THE TOTAL NUMBER OF MEN OF EACH CLASS OF LABOR EMPLOYED ON HIS DIVISION DURING THE MONTH AND WAGES PAID.

FORCE EMPLOYED IN THE LOCOMOTIVE DEPARTMENT FOR THE MONTH ENDING ..... 18...

LOCATION.	OCCUPATION	Rates Per Hour	Rates Per Month	No. of Men	Total Amount for Day	Average Amount for Day
.....Shop Hours Worked Per Day ..... Days per Week	Mast. Mech. and Gen. Foremen Foremen Clerks and Operators Machinists Machinists' Helpers Machinists' Apprentices Boiler Makers Boiler Makers' Helpers Boiler Makers' Apprentices Blacksmiths Blacksmiths' Helpers Blacksmiths' Apprentices Steam Fitters and Helpers Carpenters Painters and Helpers Coppersmiths and Tinners Engine Inspectors Stationary Engineers Callers Boiler Washers Firing up Locomotives Watchmen Laborers and Sweepers Wipers Pitmen & F. Box Cleaners Oil and Sandmen Teamsters Telephone Boys Bolt Cutters Truck Repairers Riggers and Wheelmen Tool Boys Flue Cleaners TOTAL					
..... Shop Hours Worked Per Day ..... Days per Week	Foremen Clerks and Operators Machinists Machinists' Helpers Machinists' Apprentices Boiler Makers Boiler Makers' Helpers Boiler Makers' Apprentices Blacksmiths Blacksmiths' Helpers Blacksmiths' Apprentices Pilotors and Helpers Tinners and Helpers Carpenters Truck Repairers Boiler Washers Stationary Engineers Stationary Firemen Firing up Locomotives Wipers Turn Table and Pitmen Sandmen Laborers and Sweepers Callers Oilmen Engine Inspectors Flue Cleaners Firebox Cleaners Bolt Cutters Steam Fitters and Helpers Tool Room Men Drillers Watchmen Tool Boys TOTAL					
..... Shop Hours Worked Per Day..... Days per Week ...	Foremen Boiler Washers Wipers and Laborers Callers and Telephone Boys Machinists Machinists' Helpers Boiler Makers Boiler Makers' Helpers Blacksmiths Blacksmiths' Helpers Turn Table and Pitmen Stationary Engineers Flue Cleaners Firing up Men Oil and Sandmen TOTAL					
.....Shop Hours Worked Per Day..... Days per Week	Foremen Machinists Machinists' Helpers Turn Table and Pitmen Callers Wipers and Laborers Boiler Washers TOTAL					
.....Shop Hours Worked Per Day..... Days per Week	Foremen Inspectors Boiler Makers Boiler Makers' Helpers Machinists Machinists' Helpers Wipers and Laborers Boiler Washers Turn Table and Pitmen Callers Oil and Sandmen TOTAL					
.....Shop Hours Worked Per Day..... Day per Week	Foremen Inspectors Boiler Makers Boiler Makers' Helpers Machinists Machinists' Helpers Firing up Men Wipers and Laborers Boiler Washers Turn Table and Pitmen Callers Oil and Sandmen TOTAL					
OUTSIDE POINTS	Wipers Laborers Stationary Engineers TOTAL Total for Division					

M. P. Form 62

SUMMARY MADE BY SUPERINTENDENT OF MOTIVE POWER AND MACHINERY FOR THE GENERAL MANAGER OF THE TOTAL NUMBER OF MEN OF EACH CLASS OF LABOR AND WAGES PAID ON WHOLE ROAD.

DETAIL OF FORCE EMPLOYED IN LOCOMOTIVE DEPARTMENT AT PRINCIPAL SHOP ON THE LAST DAY OF....., 19...

HOURS WORKED PER DAY.....

DEPARTMENT	OCCUPATION	RATES PER HOUR	RATES PER MONTH	No. of Men	Total Amount Per Day	Average Amount Per Day
OFFICE	Supt. M. P. and M. and Asst. Roster Mechanic and General Foreman Clerks Draughtsmen and Mechanical Engineer Operators Messengers Air Brake and Heating Inspectors Blue Print Clerks Total					
MACHINE SHOP—Tool Floor	Foremen and Gang Bosses Machinists Helpers and Handy Men Apprentices Watchmen Drillers Belt Cutters Stationary Firemen Piece Work Inspectors Laborers Oilers Timers and Helpers Shop Clerks Total					
TOOL ROOM	Foremen Mechanists Helpers and Handy Men Apprentices Drillers Laborers Total					
AIR BRAKE ROOM	Foremen Machinists Helpers and Handy Men Drillers Total					
MANUFACTURING DEPARTMENT	Foremen Machinists Helpers and Handy Men Apprentices Drillers Total					
MACHINE SHOP Basement Floor	Foremen and Gang Bosses Steam Shovel Inspector Machinists Helpers and Handy Men Machinists' Apprentices Laborers Steam Fitters Steam Fitters' Helpers Truck Repairers Total					
BOILER SHOP	Foremen and Gang Bosses Blacksmiths Boilermakers Helpers and Holderers Apprentices Flue Setters Flue Welders Rivet Heaters Drillers Total					
WHEEL SHOP	Foremen Machine Men Helpers and Laborers Total					
TANK SHOP	Foremen and Gang Bosses Watchmen Boilermakers Helpers and Handy Men Apprentices Truckmen Drillers Rivet Heaters Total					
BLACKSMITH SHOP	Foremen Stationary Engineers Furnace Firemen Spring Makers Hammersmiths Hasters Framemakers Hammermen Blacksmiths Helpers Laborers Shearmen Hammer Drivers Apprentices Total					
PAINT SHOP	Foreman Painters Helpers and Laborers Total					
CARPENTER SHOP	Foreman Carpenters Laborers and Apprentices Plasterers Total					
FOUNDRY	Foremen Hasters Moulders Core Makers Laborers Total					
TIN AND COPPER SHOP	Foremen Tinners Tinners Helpers and Apprentices Total					
POWER HOUSE	Chief Engineer and Assts. Firemen Electricians and Helpers Helpers Total					
SHOP AND YARD LABORERS	Foremen Laborers Total					
	Total Principal Shop Total Balance of System Grand Total					

ACTUAL PAY ROLLS FOR THE MONTH OF ..... 19....

DIVISION	Month of ....19..	Month of ....19..	INCREASE	DECREASE	Month of ....19..	Month of ....19..	INCREASE	DECREASE
Totals								

DIVISION	HOURLY MEN			MONTHLY MEN		WHOLE FORCE	
	Hours Worked Per Day	Number of Men	Amount Paid Per Day	Number of Men	Amount Paid Per Day	Number of Men	Amount Paid Per Day
Totals							

M. P. Form 63

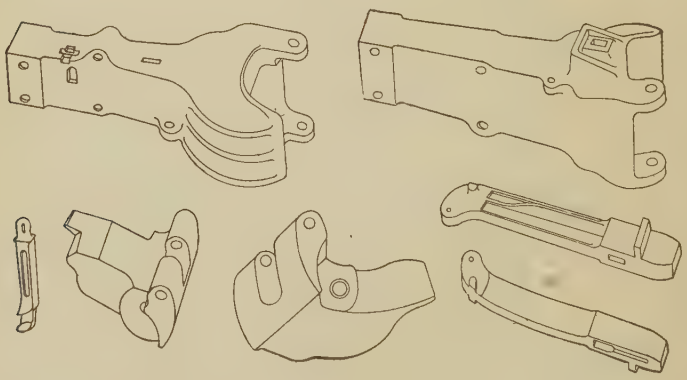
REPORT OF BREAKAGES OF LOCOMOTIVE PARTS

PILOT COUPLER

Engine No. ..... } Date found on inspection..... ..... 19 ...
or
Class ..... } Date of failure.....19.... Reported at.....

NOTE.—The location of all fractures should be indicated with red ink lines and the dimensions given to some fixed point.

The questions relating to the fractures at the bottom of this form should be answered as explicitly as possible and the report sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.



Kind of metal.

Was there flaw at point of fracture?

Was there an old crack?

Probable cause of failure.

REMARKS :

.....

.....

.....

..... Master Mechanic

M. P. Form 64

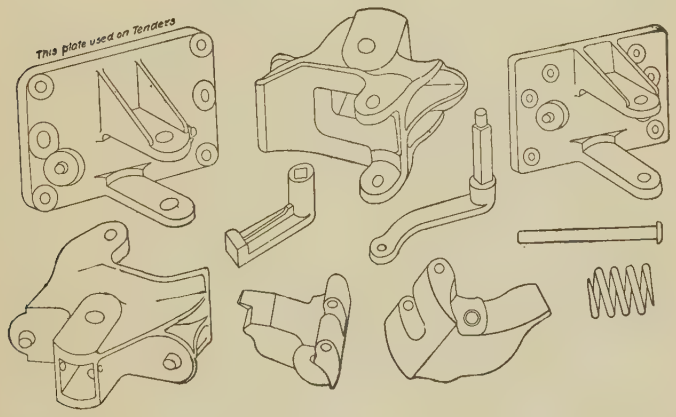
REPORT OF BREAKAGES OF LOCOMOTIVE PARTS.

PLATE COUPLER

Engine No.....} Date found on inspection.....19....
or
Class.....} Date of failure.....19.... Reported at.....

The location of all fractures should be indicated with red ink lines, and the dimensions given to some fixed point.

The questions relating to the fractures at the bottom of this form should be answered as explicitly as possible and the report sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.



Kind of metal.

Was there flaw at point of fracture?

Was there an old crack?

Probable cause of failure

REMARKS:

.....

.....

.....

.....

..... Master Mechanic

M. P. Form 35

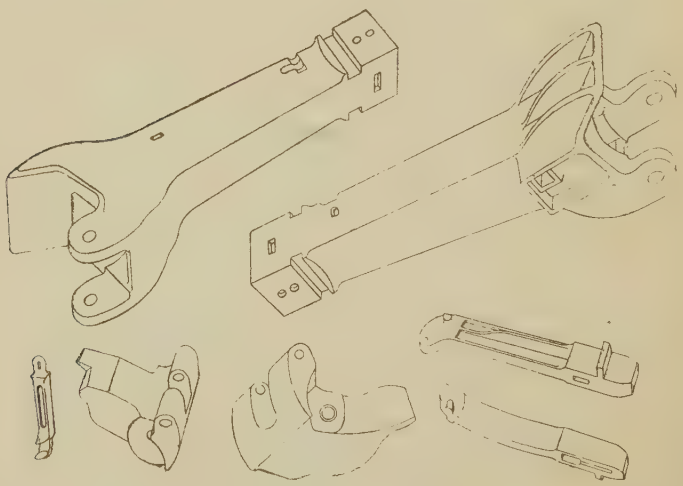
REPORT OF BREAKAGES OF LOCOMOTIVE PARTS

M. C. B. COUPLER

Engine No. ..... } Date found on inspection 19
Class ..... } or Date of failure ..... 19 .... Reported at .....

NOTE.—The location of all fractures should be indicated with red ink lines, and the dimensions given to some fixed point.

The questions relating to the fractures at the bottom of this form should be answered as explicitly as possible, and the report sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.



Kind of metal.

Was there flaw at point of fracture?

Was there an old crack?

Probable cause of failure.

REMARKS:

..... Master Mechanic

M. P. Form 66

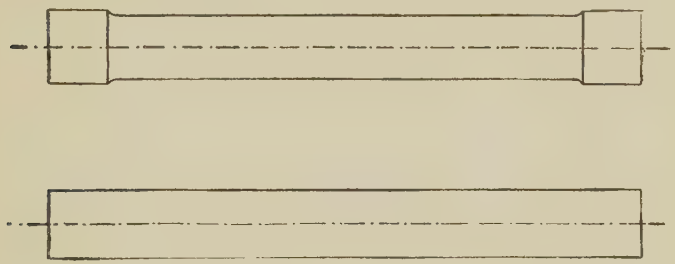
REPORT OF BREAKAGES OF LOCOMOTIVE PARTS.

AXLE.

Engine No. ..... } Date found on inspection ..... 19..
Class ..... } or Date of failure ..... 19.... Reported at .....

NOTE.—The location of all fractures should be indicated with red ink lines, and the dimensions given to some fixed point.

The questions relating to the fractures at the bottom of this form should be answered as explicitly as possible, and the report sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.



Was it driving or truck axle? .....

Dimension and, if possible, sketch of section at point of fracture.

Kind of Metal .....

Was it front, middle or back axle? .....

Was the metal homogeneous? .....

Date put in service. .....

Was there flaw at point of fracture? .....

Probable cause of failure. .....

.....

Master Mechanic.

M. P. Form 67

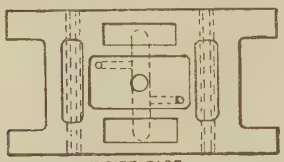
REPORT OF BREAKAGES OF LOCOMOTIVE PARTS.

DRIVING BOX AND BRASS.

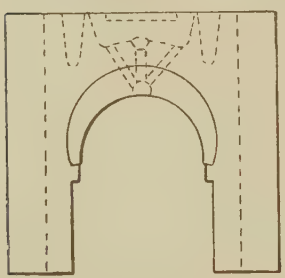
Engine No. ..... } Date found on inspection.....19....
or
Class ..... } Date of failure.....19.. Reported at .....

NOTE.—The location of all fractures should be indicated with red ink lines and the dimensions given to some fixed point.

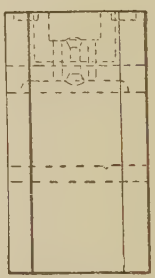
The questions relating to the fractures at the bottom of this form should be answered as explicitly as possible and the report sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery



INSIDE FACE.



BOX



BRASS

Pattern No.....

Dimension and, if possible, sketch of section at point of fracture:

Was it front, back or middle?

.....

Kind of metal.....

Was there flaw at point of fracture?.....

Probable cause of failure?.....

Pattern No.....

Dimension and, if possible, sketch of section at point of fracture:

Was it front, back or middle?

.....

Kind of metal .....

Was there flaw at point of fracture?.....

Probable cause of failure?.....

.....

Master Mechanic.

M. P. Form 68

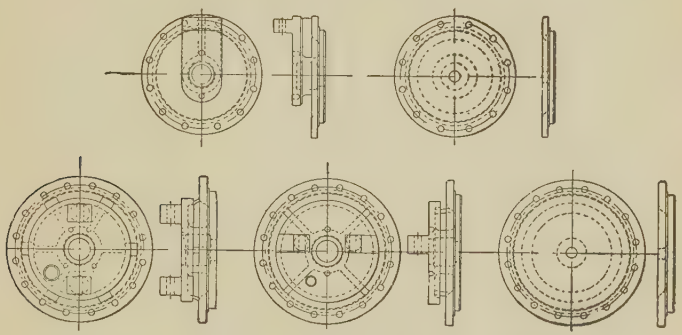
REPORT OF BREAKAGES OF LOCOMOTIVE PARTS.

CYLINDER HEADS.

Engine No. ..... } Date found on inspection ..... 19....
Class ..... } or Date of failure ..... 19.... Reported at .....

NOTE.—The location of all fractures should be indicated with red ink lines and the dimensions given to some fixed point.

The questions relating to the fractures at the bottom of this form should be answered as explicitly as possible, and the report sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.



BACK HEAD. FRONT HEAD.

BACK HEAD.	FRONT HEAD.
Pattern No.	Pattern No. .....
Dimensions and, if possible, sketch of section at point of fracture.	Dimensions and, if possible, sketch of section at point of fracture.
Kind of metal	Kind of metal .....
Was there flaw at point of fracture?	Was there flaw at point of fracture? .....
Probable cause of failure	Probable cause of failure .....

.....

Master Mechanic.

M. P. Form 69

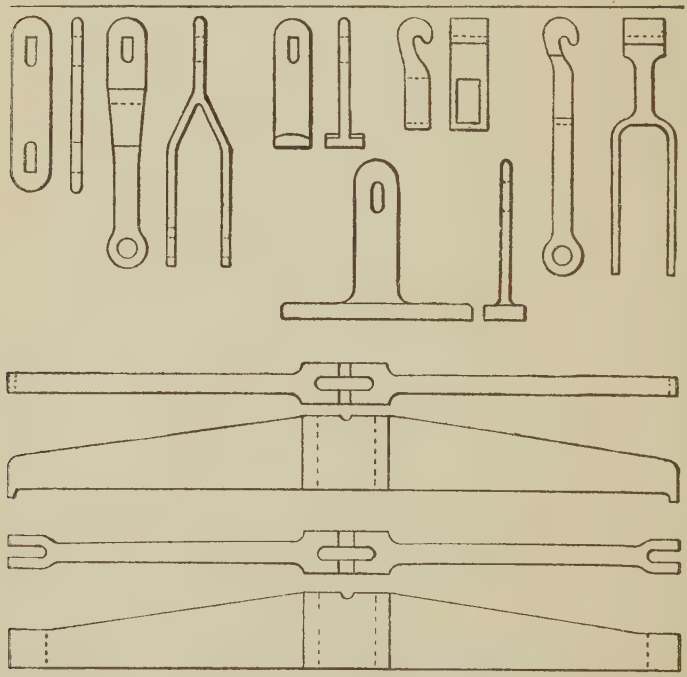
REPORT OF BREAKAGES OF LOCOMOTIVE PARTS.

EQUALIZER. EQUALIZER STAND. SPRING HANGERS.

Engine No..... } Date found on inspection.....19.....
or
Class ..... } Date of failure.....19.....Reported at.....

NOTE.—The location of all fractures should be indicated with red ink lines and the dimensions given to some fixed point.

The questions relating to the fractures at the bottom of this form should be answered as explicitly as possible, and the report sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.



EQUALIZER.	EQUALIZER STAND.	SPRING HANGERS.
Dimension and, if possible, sketch of section at point of fracture.	Dimension and, if possible, sketch of section at point of fracture.	Dimension and, if possible, sketch of section at point of fracture.
Kind of metal.	Kind of metal.	Kind of metal.
Was there flaw at point of fracture?	Was there flaw at point of fracture?	Was there flaw at point of fracture?
Probable cause of failure.	Probable cause of of failure.	Probable cause of failure?

.....

Master Mechanic.

M. P. Form 70.

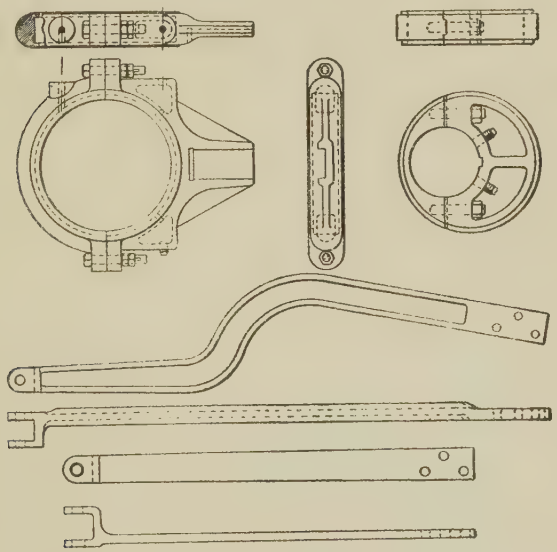
REPORT OF BREAKAGES OF LOCOMOTIVE PARTS.

ECCENTRIC, ECCENTRIC STRAP, ECCENTRIC ROD.

Engine No. ..... Date found on application.....19.....
or
Class..... Date of failure.....19.....Reported at.....

NOTE.—The location of all fractures should be indicated with red ink lines and the dimensions given to some fixed point.

The questions relating to the fractures at the bottom of this form should be answered as explicitly as possible and the report sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.



ECCENTRIC	ECCENTRIC STRAP	ECCENTRIC ROD
Pattern No.....	Pattern No.....	Dimensions, and if possible, sketch of section at point of fracture.
Forward..... Back.....	Forward .....Back.....	
Dimensions, and if possible, sketch of section at point of fracture.	Dimensions, and if possible, sketch of section at point of fracture.....	
Kind of metal.....	Kind of metal.....	Kind of metal .....
Was there flaw at point of fracture?	Was there flaw at point of fracture?	Was there flaw at point of fracture?.....
Probable cause of failure.	Probable cause of failure.	Probable cause of failure.

.....

MASTER MECHANIC.

M. P. Form 71

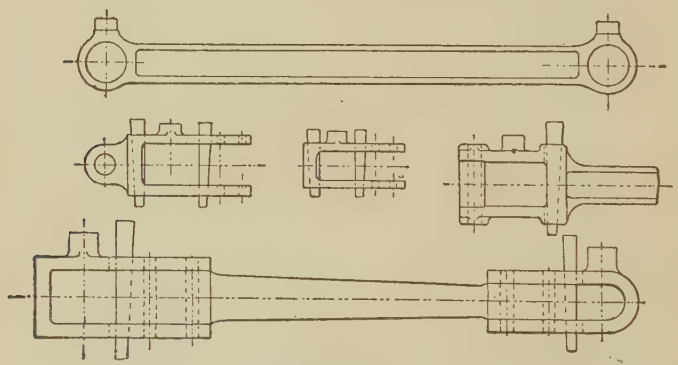
REPORT OF BREAKAGES OF LOCOMOTIVE PARTS.

SIDE ROD, MAIN ROD AND ROD STRAP.

Engine No. ..... } Date found on inspection ..... 19....
Class ..... } or Date of failure ..... 19.... Reported at .....

NOTE.—The location of all fractures should be indicated with red ink lines and the dimensions given to some fixed point.

The questions relating to the fractures at the bottom of this form should be answered as explicitly as possible, and the report sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.



SIDE ROD.	MAIN ROD.	ROD STRAP.
Front end, ...	Dimension, and if possible, sketch of section at point of fracture, ...	Front strap, ...
Back end, ...		Back strap, ...
Dimensions and if possible sketch of section at point of fracture		Dimension, and if possible, sketch of section at point of fracture .....
Kind of metal.	Kind of metal.	Kind of metal .....
Was there flaw at point of fracture?	Was there flaw at point of fracture?	Was there flaw at point of fracture .....
Probable cause of failure.	Probable cause of failure.	Probable cause of failure. .....

.....
Master Mechanic.

M. P. Form 72

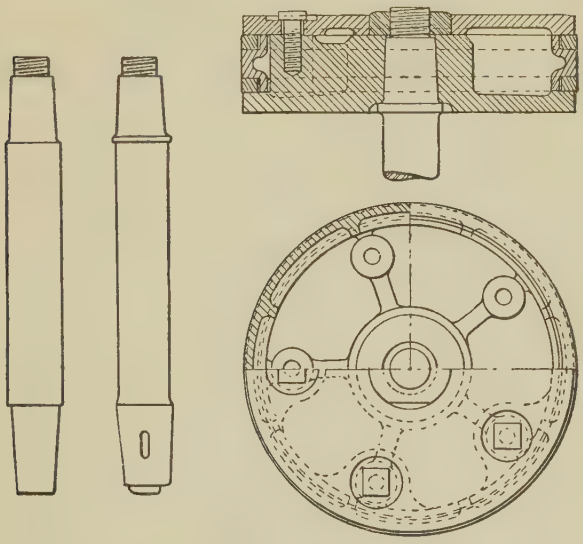
REPORT OF BREAKAGES OF LOCOMOTIVE PARTS.

PISTON AND PISTON RODS.

Engine No. ..... } Date found on inspection ..... 19....
or
Class ..... } Date of failure ..... 19.... Reported at .....

NOTE.—The location of all fractures should be indicated with red ink lines and the dimensions given to some fixed point.

The questions relating to the fractures at the bottom of this form should be answered as explicitly as possible, and the report sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.



PISTON.	PISTON FOLLOWER.	PISTON ROD
Pattern No. { Bull-ring / Spider	Pattern No.	Enlarged ends .....
Dimensions and, if possible, sketch at point of fracture.	Dimensions and, if possible, sketch at point of fracture.	Dimensions and, if possible, sketch at point of fracture.
Kind of metal		
Kind of packing		Kind of metal .....
Front packing-ring		Was there flaw at point of fracture? .....
Back packing-ring	Kind of metal	Did it show any old crack? .....
Was there blow-hole or flaw at point of fracture?	Was there blow-hole or flaw at point of fracture?	Shop letter and date put in .....
Probable cause of failure	Probable cause of failure.	Probable cause of failure .....

.....

Master Mechanic.

M.P. Form 73

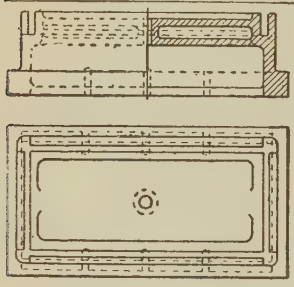
REPORT OF BREAKAGES OF LOCOMOTIVE PARTS.

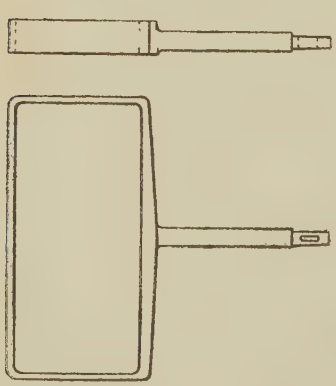
VALVES, VALVE YOKES AND ROCKER SHAFT.

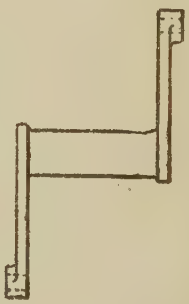
Engine Number.....Date of failure.....
Reported at.....19....

NOTE.—The location of all fractures should be indicated with red ink lines and the dimensions given to some fixed point.

The questions relating to the fractures at the bottom of this form should be answered as explicitly as possible, and the report sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.







VALVE.	VALVE YOKE.	ROCK SHAFT.
Pattern No.	Kind of metal	Pattern No. .....
Kind of metal	Dimensions and, if possible, sketch of section at point of fracture.	Kind of metal .....
Dimensions and, if possible, sketch of section at point of fracture.	Was there flaw at point of fracture?	Dimensions and, if possible, sketch of section at point of fracture.
Kind of valve.....	Probable cause of failure.	Was there flaw at point of fracture?
Kind of balancing.....		Probable cause of failure?.....
Was there flaw at point of fracture?		
Probable cause of failure.		

.....Master Mechanic.

M. P. Form 74

REPORT OF BREAKAGES OF LOCOMOTIVE PARTS

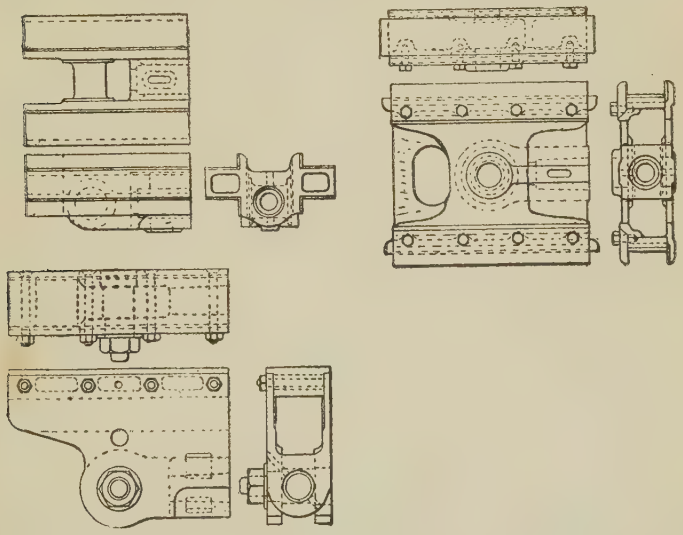
CROSSHEADS.

FOUR-BAR CROSSHEAD. LAIRD CROSSHEAD. TWO-BAR CROSSHEAD.

Engine Number.....Date of failure.....
Reported at.....19....

NOTE.—The location of all fractures should be indicated with red ink lines and the dimensions given to some fixed point.

The questions relating to the fractures at the bottom of this form should be answered as explicitly as possible, and the report sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.



FOUR-BAR CROSSHEAD.	LAIRD CROSSHEAD.	TWO-BAR CROSSHEAD.
Pattern No	Pattern No.	Pattern No. .....
Kind of metal	Kind of metal	Kind of Metal .....
Dimensions and, if possible, sketch of section at point of fractu e.....	Dimensions and, if possible, sketch of section at point of fracture.	Dimensions and, if possible, sketch of section at point of fracture.
Was there flaw at point of fractu e?	Was there flaw at point of fracture?	Was there flaw at point of fracture? .....
Probable cause of failure	Probable cause of failure.	Probable cause of failure. .....

.....

Master Mechanic.

M. P. Form 75

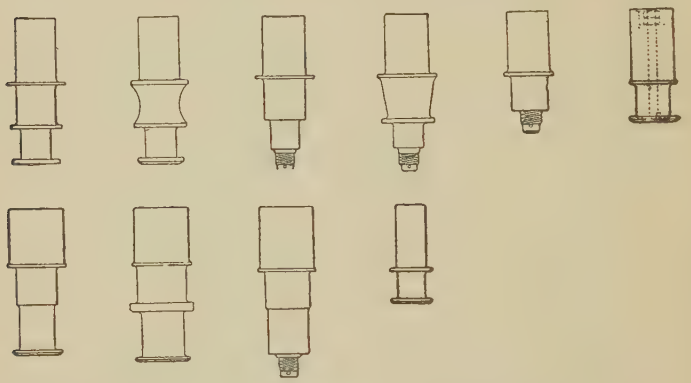
REPORT OF BREAKAGES OF LOCOMOTIVE PARTS.

CRANK PINS.

Engine No. ..... } Date found on inspection..... 19....
Class..... } or Date of failure..... 19.... Reported at.....

NOTE.—The location of all fractures should be indicated with red ink lines and the dimensions given to some fixed point.

The questions relating to the fractures at the bottom of this form should be answered as explicitly as possible, and the report sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.



MAIN PIN.	BACK PIN.	FRONT PIN.
Dimensions and, if possible, sketch at point of fracture.	Dimensions and, if possible, sketch at point of fracture.	Dimensions and, if possible, sketch at point of fracture.
Kind of metal	Kind of metal	Kind of metal .....
Was there flaw at point of fracture?	Was there flaw at point of fracture?	Was there flaw at point of fracture? .....
Was there an old crack?.....	Was there an old crack?	Was there an old crack?.....
Did fracture show crystalization?	Did fracture show crystalization?.....	Did fracture show crystalization? .....
About how long in service?	About how long in service?	About how long in service? .....
Probable cause of failure	Probable cause of failure.	Probable cause of failure.....

.....
Master Mechanic.

M. P. Form 76

REPORT OF BREAKAGES OF LOCOMOTIVES PARTS STAY-BOLTS.

Engine No.....at..... Date ....19....

Inspected by .....

NOTE.—This report should show the condition of the fire-box sheets of each engine receiving boiler repairs and should be forwarded to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.

All broken stay-bolts, cracks, patches or defects must be shown hereon as found at each inspection, and whenever repairs are made to fire-box sheets.

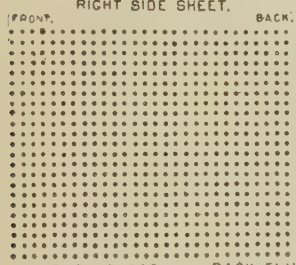
Each broken stay-bolt should be indicated by a circle drawn around it with red ink; those otherwise defective, by a red ink cross.

New patches should be shown on the diagrams given below by red ink lines; old patches, and size of sheets by black ink lines.

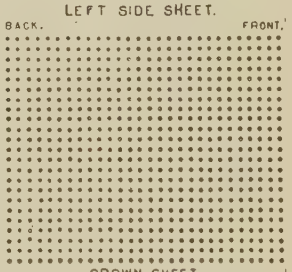
The laboratory number of all new sheets must be shown in the space provided.

Name of Sheet	Number Broken	Diameter of Bolts		Lab'rat'ry Number of New Sheets	REMARKS
		Removed	Applied		

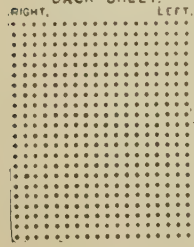
RIGHT SIDE SHEET.



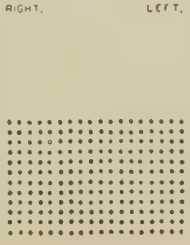
LEFT SIDE SHEET.



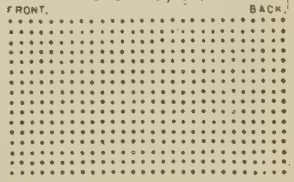
BACK SHEET.



BACK FLUE SHEET.



CROWN SHEET.



.....

Master Mechanic

M. P. Form 77

REPORT OF BREAKAGES OF LOCOMOTIVE PARTS

MISCELLANEOUS

Engine No. { Date found on inspection.....19....
or
Class .. .. { Date of failure.....19....Reported at.....

Hauling.....Section Train No.....

REMARKS : .....

.....

.....

.....

.....

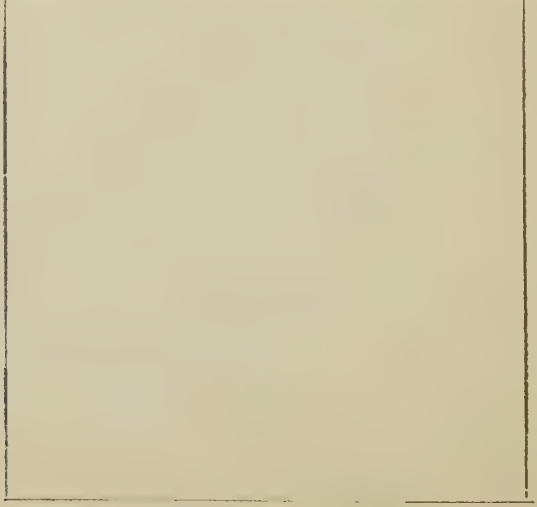
.....

Master Mechanic.

NOTE.—This report should be used in reporting all breakages of locomotive parts for which special forms are not provided.

A sketch should be made of the part broken and all fractures indicated thereon with red ink lines, and the dimensions given to some fixed point.

The report should be sent to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.



M. P. Form 78

REPORT OF CONDITION OF LOCOMOTIVE BOILER

ENG. NO.....

INSPECTED AT.....DATE.....19....

TEST PRESSURE .....LBS.

LABORATORY NOS. OF NEW PLATES	REMARKS.

NOTE.—This report should show the condition of the boiler of each engine receiving boiler repairs, and should be forwarded to the master mechanic for his signature, and he will forward it immediately to the Superintendent of Motive Power and Machinery.

The size of all new patches should be indicated on the diagrams given below, by red ink lines, and old patches by black ink lines.

The laboratory number of all new sheets must be shown in the space provided.

The condition of the fire-box sheets should be shown on Form 76.

INSPECTED BY

Fig 3.

Fig 1

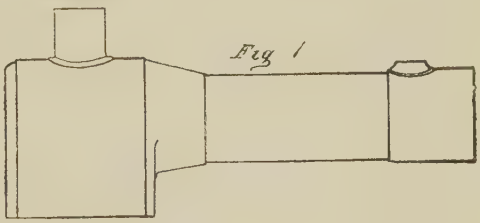
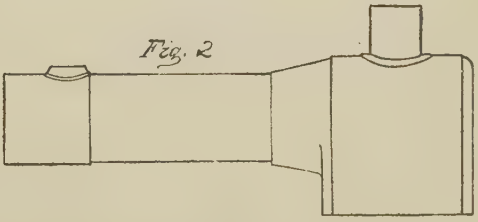


Fig 4

Fig. 2



MASTER MECHANIC.

M. P. Form 79

INSPECTOR'S RECORD OF INSPECTION OF STATIONARY AND LOCOMOTIVE FIRE-BOX STAY-BOLTS

AT.....SHOP

NOTE.—Stay-bolts in locomotive engines must be inspected monthly, and in stationary engines quarterly, and all bolts found defective replaced before engine is allowed to go into service.

The information called for below should be filled in by the person making the inspection and replacing the bolts, at the time of inspection or replacement, and signed by such person in the space provided.

Engine Number	DATE OF INSPECTION			NUMBER OF DEFECTIVE STAY BOLTS				INSPECTOR'S SIGNATURE	ALL BROKEN STAY-BOLTS WERE REPLACED			
									DATE			
	Month	Day	Year	Front Sheet	Back Sheet	Right Sheet	Left Sheet		Month	Day	Year	By Whom

M. P. Form 80

INSPECTOR'S MONTHLY REPORT OF INSPECTION OF STATIONARY AND LOCOMOTIVE FIRE-BOX STAY-BOLTS.

AT.....SHOP .....DIVISION. DURING THE MONTH OF.....19....

NOTE.—A report of this form must be made in duplicate by each inspector on the first day of the month for the inspection of all locomotive boilers, and quarterly for all stationary boilers, under his supervision.

Both reports, after having been signed in the space provided, by the person making the inspection and replacing the bolts, should be forwarded to the division master mechanic, who, after making an examination of the reports, will retain one copy for his office record, and forward the other to the office of the Superintendent of Motive Power and Machinery. The information shown hereon should be an exact copy of Form 79.

All stationary boilers should be shown on a separate report and the numbers of same prefixed by the letter "S." The point where they are located should be shown above the line in which the number of the engine is entered.

Engine Number	DATE OF INSPECTION	NUMBER OF DEFECTIVE STAY-BOLTS				INSPECTOR'S SIGNATURE	ALL BROKEN STAY-BOLTS REPLACED	
		Front Sheet	Back Sheet	Right Sheet	Left Sheet		Date	By Whom

M. P. Form 81

INSPECTOR'S REPORT OF PERIODICAL INSPECTION OF STATIONARY BOILERS.

At.....Shops.....Division. Date .....19..

NOTE.—The annual inspection of stationary boilers should be made during the months of May and June. Two reports of this character must be filled out and signed by the person making the inspection at the time and place such inspection is made. One of the reports will be filed in the office of the master mechanic, and the other sent to the Superintendent of Motive Power and Machinery.

The inspection will include the application of hydrostatic pressure 25% above the working pressure carried. The water should be hot when pressure is applied. This should be followed by a close inspection of all plates, seams, braces, fittings, setting, etc., and any defects discovered must be remedied before the boiler is again put into service.

Boiler No.	Location	Working Pressure Carried	Test Pressure	Condition	Repairs Needed	Date Tested	Inspector's Signature

Signed.....

.....
Master Mechanic.

M. P. Form 82

INSPECTOR'S REPORT OF INSPECTION OF AIR AND STEAM GAUGES AND SAFETY VALVES

AT.....SHOP. .....DIVISION. DATE.....19.....

NOTE.—All air and steam gauges and safety valves must be tested quarterly.

Two reports of this character must be filled out and signed by the person making the inspection at the time and place such inspection is made. One of the reports will be filed in the office of the master mechanic, and the other forwarded to the Superintendent of Motive Power and Machinery.

When steam gauges are applied, extreme care must be taken to provide a large syphon and to have the same full of water before turning the steam into the gauge. This applies with equal force to the test gauge.

A separate report should be made for stationary boilers and the point at which they are located should be shown hereon and the numbers prefixed by the letter "S."

Eng. or Boiler Number	Date Tested	Location	AIR GAUGE					STEAM GAUGE			SAFETY VALVE		
			Train Line		Reservoir		Remarks						
			Test Gauge	Eng. Gauge	Test Gauge	Eng. Gauge		Test Gauge	Eng. Gauge	Remarks	Blow Off	Blow Down	Remarks

M. P. Form 83

INSPECTOR'S REPORT OF CHANGES AND REPAIRS OF STATIONARY BOILERS.

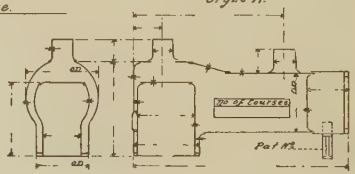
NOTE—This report is to be made at stated intervals or whenever any changes are made in stationary boilers, by the foreman or inspector and forwarded to the Superintendent of Motive Power and Machinery.

The items and dimensions should be given as called for on the diagram below.

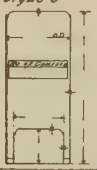
All dimensions of the shell should be outside dimensions and those of the firebox inside dimensions. All seams should be located on the boiler diagrams by use of the seam diagrams and numbers on the opposite section of this form. If any other style of seam is used a sketch should be made in the blank space provided for that purpose.

Boiler No.	Date.
Location.	
Service.	
Boiler Press. Max	
" " Working	
Builder.	
Built.	
Installed.	
Boiler Material	
Tubes Number.	
" Diam.	
" Length.	
" Gauge.	
Fire Box Length	
" " Width	
" " Diam	
" " Height.	

Style A.

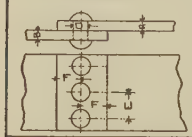


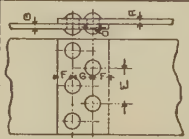
Style C.

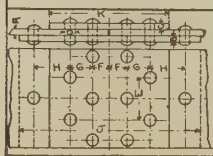


Style D.

SEAM DIAGRAMS







DIMENSIONS OF SEAMS

*	A	B	C	D	E	F	G	H	J	K
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										

*Number of Seams as shown on Boiler Diagrams

M. P. Form 84

SHOP FOREMAN'S REPORT TO MASTER MECHANIC OF VALVE MOTION OF ENGINES.

Engine No._____ Class._____

_____ Shops. Date._____ 19____

NOTE—This report should be made by the foreman of the shops where engines are repaired and sent to the master mechanic for his signature, and any notations which he may make, who will in turn forward same to the Superintendent of Motive Power and Machinery.

The report should show the dimensions of the parts enumerated below.

Cylinders		Throw of Eccentric	
Steam Ports	x	Travel of Valve	
Exhaust Port	x	Saddle Pin Back	
Bridges		Lead Full Gear	
Outside Lap		Valves Set by	
Inside Clearance			

	Reverse Lever Notch	Cut Off Front End.	Cut Off Back End.	Difference in Cut Off	Exhaust Open. Front.	Exhaust Open. Back.	Difference in Exhaust Opening.	Exhaust Closes. Front.	Exhaust Closes. Back	Difference in Exhaust Closure.	Lead Front	Lead Back.	Maximum Port Opening
FORWARD MOTION.													
BACK MOTION.													

REMARKS:_____

_____

_____

_____

_____

MASTER MECHANIC.

M. P. Form 85

MONTHLY REPORT OF EACH ENGINEER'S SERVICE, VIZ: TOTAL MILES RUN BY LOCOMOTIVES UNDER HIS CHARGE, TONS HAULED AND FUEL CONSUMED.

....Division. For the month of.....19....

NOTE.—This report is made monthly by each master mechanic and should be sent to the office of the Superintendent of Motive Power and Machinery by the fifteenth day of the month. A separate report should be made for each kind of service—as passenger, freight, etc.

.....*Service.*

Engineer	Fireman	Run Between or Location	Train No.	Engine No.	Total Mileage	Tons of Coal Used	Miles Run Per Ton	Ton Miles	Lbs. Coal Us'd Per 100 Ton Miles	Average Tons per Train

M. P. Form 86

STATEMENT OF MILEAGE MADE BY EACH ENGINEER TO PINT OF LUBRICATING OIL.

ON.....DIVISION. FOR THE MONTH OF.....19....

NOTE.—This report is to be made monthly by each master mechanic and should be sent to the office of the Superintendent of Motive Power and Machinery by the twentieth day of the month. A separate report should be made for each kind of service.

.....SERVICE

ENGINEER	Engine No.	Total Mileage Made	Pints of Engine Oil	Pints of Cylinder Oil	Total pints of Lubricating Oil	Average Number of Miles Run to pint of			Total Cost of Lubricating Oils		Cost per 1000 Engine Miles
						Eng. Oil	Cylinder Oil	Lubricating Oil			

M. P. Form 87

MASTER MECHANIC'S REPORT TO SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF CONDITION OF TOOLS AND MACHINERY.

.....Shop. Date.....19....

KIND	DESCRIPTION	MAKER'S		Location	Sub-Shop	Date Placed in Service	Cost When New		Estimated Value at Jan. 1, 19....		Present Condition	REMARKS
		Name	No.									

M. P. Form 88

FORM OF APPLICATION MADE BY THOSE SEEKING EMPLOYMENT ON ENGINES.

INSTRUCTIONS.—All applications for employment as engineers, firemen, engine dispatchers, and such other employes as may be designated by the division superintendent or master mechanic, must be made by the applicant himself, in duplicate, on this blank, and sworn to before a notary public. The applicant will then report to the Company's surgeon to have his sight and hearing tested, and for physical examination also. surgeons making such tests and examinations will report results of same in proper place on this blank, sending one report to the division superintendent or master mechanic, and the other to the chief surgeon. A fee of one dollar will be charged for making such examinations, and the same will be paid by the Company, unless the applicant is accepted as an employe, in which case, the amount of the fee will be deducted from his wages.

NOTE.—When this application blank is properly filled out and sworn to, the applicant may be allowed to enter the service ON PROBATION, provided there is need for his services, and he has passed a satisfactory examination, but it must be distinctly understood that before he can be considered an ACCEPTED employe, the written approval of the superintendent or master mechanic must be obtained.

Full Name and Address of Applicant.

.....

.....

.....

Place .....

Date .....19....

1. Place of birth.....Date of birth.....18. . Age.....
2. Single or married?.....
3. Give names and address of any persons dependent on you for support or to whose support you are contributing .....
4. What position do you desire? .....
5. What experience have you had in that line?.....
6. By whom are you employed at present? .....
   No.....Street....., Town or City....., State of.....
7. In what capacity are you employed?.....
8. Are any of your relatives in the employ of this Company? If so, state who they are, and in what capacity employed.....
9. State below where and how you have been employed since you left school, making no omission in the record:

Time of Service				NAME OF EMPLOYER (If the employer was a corporation, give name of such corporation; also name and present address of official under whom you served.)	Place Where Employed	Nature of Empl'ym't How Employed	Why Did You Leave?
FROM		TO					
Month	Year	Month	Year				

10. Give below the name, address and occupation of your parents and other relatives. If any are deceased, give other nearest relatives:

NAME	OCCUPATION	ADDRESS
Father:		
Mother:		
Nearest Male Relative On Father's Side:		
On Mother's Side:		

11. Have you ever been discharged or suspended from any situation? If so, state particulars, when and where.....
12. Have you ever been injured? If so, when.....where.....
how .....
and extent of injuries.....
13. Have you now or did you ever have any litigation with any railroad company?.....
14. Have you ever been in the employ of this company before? If so, state when, where, in what capacity, and cause of leaving.....
15. Do you drink malt or spirituous liquors?.....
16. Have you ever before made application for employment and been subjected to a physical examination? If so, when.....
where.....and by what physician was examination made?.....
17. Were you accepted or rejected?.....

I hereby authorize this company and its officers, and the officers of any other company or firm by which I have been heretofore employed, to answer any or all inquiries as to my conduct and qualifications while in such service, and, so far as they may know, the cause of my leaving the same.

In consideration of my employment by said company, I further agree that whenever I shall sustain any personal injury while in the service of said company I will allow its surgeons and any medical examiners it may select to examine my person and body as often as the company may deem necessary in respect to the alleged injury, and I hereby waive all objections to such surgeons or medical examiners testifying whenever called upon by the company, and I further agree that my refusal to allow any such examination to be made or testimony to be given shall be a bar to the institution or prosecution of any action on account of such injuries; and any action pending at the time of such refusal shall at once abate in consequence thereof.

In further consideration of such employment I agree that if, while in the service of said company, I sustain any personal injury for which I shall or may make claim against the company for damages I will, within sixty days after receiving such injury, give notice in writing of such claim to the general claim agent of said company; which notice shall state the time, place, manner and cause of my being injured and the nature and extent of my injuries, and the claim made therefor, to the end that such claim may be fully, fairly and promptly investigated; and my failure to give written notice of such claim in the manner and within the time aforesaid, shall be a bar to the institution of any suit on account of such injuries.

Signature of Applicant.....

Address .....

Dated at.....this..... day of .....19....

STATE OF .....
} ss.
COUNTY OF .....

.....being first duly sworn, says that he is the applicant named in the foregoing application, that said application, is signed by him, and that the answers to questions in said application are made in his own hand-writing, and that each and all of the answers contained in said application are true.

.....

Subscribed and sworn to before me this.....day of ..... 19....

.....

Notary Public.

I hereby acknowledge receipt of a copy of the rules and regulations for the government of employes of the operating department of the.....Railway Company, and all amendments thereto, and also a copy of the current time table, and agree to familiarize myself with and observe all the same, and to keep advised of such amendments to said rules as may be hereafter made, and have had explained to me the dangerous nature of the service in which I am about to engage. I have been notified that there are buildings, coal chutes, signal posts, switch stands, round house doors and other obstructions dangerously close to the tracks, and that I am required to look out for them and avoid danger, which I fully appreciate.

Dated at.....this.....day of.....19....

.....

SURGEON'S CERTIFICATE.

To be filled out and signed after a PERSONAL examination by any of the company's local surgeons.

The followng is the report of the result of my examination of Mr.....

.....

TO BE SIGNED BY APPLICANT IN PRESENCE OF EXAMINER.

1. When placed at a distance of twenty (20) feet from the test types, the last five (5) letters read correctly by the applicant are:
   Right eye.....20/.....
   Left eye .....20/.....
   Both eyes .....
2. A. The applicant selects skeins numbered as follows, as being of the same color as test skein A:
   B. The following as being of the same color as test skein B:
   C. The following as being of the same color as test skein C:
3. The applicant hears the tick of a watch with the right ear at..... inches; with the left ear at.....inches. For ordinary conversation at a distance of twenty (20) feet, the hearing is..... (expressed in fractions).

I find that there is evidence of recent successful vaccination; that he is not suffering from any disease or disability other than noted, and that he does not manifest any evidence of an abuse of intoxicating liquors.

I hereby certify that, having examined him for defects of vision, color perception and hearing, and for other physical defects, I find him } qualified / disqualified { to fill the position of.....

Disqualifying defects .....

Defects that do not disqualify.....

Remarks: .....

Examined by.....

Surgeon at.....

Date of Examination.....19.....

TO BE SIGNED BY SURGEON MAKING THE EXAMINATION.

M. P. Form 89

MASTER MECHANIC'S NOTICE OF VACANCIES IN RUNS AND SERVICE.

.....Division Date.....19.....

NOTE.—This notice is issued by the master mechanic whenever vacancies occur for engineers or firemen.

A copy should be sent to each round house foreman on the division and posted on the bulletin board or some other conspicuous place.

Applications should be made for the position desired and forwarded to the master mechanic on or before the date specified below

ENGINEER OR FIREMEN	TRAIN NO.	BETWEEN WHAT POINTS

All applications must be on file in the office of the master mechanic not later than.....19.....

M. P. Form 90

NOTICE OF SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF THOSE AUTHORIZED TO OPERATE LOCOMOTIVES

TO MASTER MECHANICS AND FOREMEN IN CHARGE OF ROUND-HOUSES AND SHOPS:

No one other than Master Mechanics, Round-House Foremen, Engineers, Firemen or Hostlers is allowed to move or operate the locomotive engines of this Company. All other employes are strictly forbidden to do so.

Any employe disobeying this order will be liable to immediate discharge. Master Mechanics and Round-House Foremen are instructed to enforce the above order rigidly, and to provide all employes under them, who are not permitted to handle locomotives under the terms of this order, with a copy of this notice, to explain it carefully to them, to procure their acknowledgment thereof on this blank and forward the same immediately to the Superintendent of Motive Power and Machinery.

.....

ACKNOWLEDGMENT OF EMPLOYE.

The above notice has this day been read and explained to me by.....

.....

and a copy thereof left in my possession. I agree to observe carefully the instructions contained therein.

Signed at.....this.....

day of.....19.....

.....

Witness:

.....

M. P. Form 91

FORM OF RELEASE TO BE SIGNED BY MINORS AND THEIR LEGAL GUARDIANS

NOTE.—This release must be furnished in duplicate by all minors before they are allowed to enter the service of the Company. It must be duly signed by the parents or guardian of the minor, witnessed by two disinterested persons and sworn to before a notary public.

One copy of the release should be kept on file in the office of the official under whom the minor is employed and the other forwarded to the Superintendent of Motive Power and Machinery.

WHEREAS,.....who was

.....years of age on the.....day of.....

19...., is about to enter the employment of the ..... RAILWAY COMPANY; and

WHEREAS, the nature of such employment may from time to time be changed:

THEREFORE, IN CONSIDERATION of his being employed by that Company, in whatever capacity now or hereafter we, the undersigned, *father and mother of said minor, do hereby agree with said Railway Company that we

have given the said..... .....his own time and earnings,

and that he is of sufficient capacity to discharge the duties of his employment, now or hereafter, and that he may at all times himself collect and receipt for his wages from said Company in whatever position he may at any time be employed, and that we will make no claim against said Company at any time for any wages or earnings of said minor in the employment of said Railway Company, or for any injuries that he may receive during or in connection with said employment, or for any liability whatever on account of said minor or his employment.

WITNESS our hands and seals at.....this.....day of

.....19.....

Witness:

..... [SEAL.]

....[SEAL.]

*If there is no father or mother and there is a guardian, the word "guardian" should be inserted instead of "father and mother," and the release executed by guardian.

I,..... referred to in the above release, do

hereby certify that I was..... ...years of age on the. .....day

of.....19...., and that the dangerous nature of the business

in which I am about to engage has been explained to me by the agents of the Company, and that I fully understand the risks I am about to take in entering

the employment of the .....RAILWAY COMPANY

as a .....

Dated at.....this..... .....day of

.....19.....

WITNESS:

....

M. P. Form 92

CERTIFICATE GIVEN ON COMPLETION OF APPRENTICESHIP.

.....RAILWAY CO.

DEPARTMENT OF MOTIVE POWER AND MACHINERY.

.....

Has served an Apprenticeship as.....

In the Shops of this Company at.....

During the period from .....to.....

WORK ON WHICH EMPLOYED.

Time Employed	Kind of Work

OFFICERS UNDER WHOM EMPLOYED.

Name	Title

GENERAL RECORD OF APPRENTICE.

.....

.....

Supt. M. P. and Machinery.

M. P. Form 93

MASTER MECHANIC'S WEEKLY REPORT TO SUPERINTENDENT OF MOTIVE POWER AND MACHINERY OF AVERAGE TERMINAL DELAYS OF FREIGHT ENGINES AND CAUSE THEREFOR

.....DIVISION. .....19....

NOTE.—A report of this character should be made daily by each round-house foreman and forwarded to the master mechanic. It should show in hours and minutes, the length of time all freight engines are held for various causes, the total time held, and the average time held per engine.

On Monday of each week the master mechanic will make a summary on this form of all such delays at the several round-houses on the division, showing the same information for the total number of engines handled at each point during the week and forward it to the Superintendent of Motive Power and Machinery.

PLACE	Total Number of Engines Handled	DATE	LENGTH OF TIME HELD						TOTAL TIME HELD		AVERAGE TIME HELD PER ENGINE		REMARKS
			For Coal, Water or Cleaning Fire		For Work on Engine in Round House		For Orders						
			Hrs.	Mins.	Hrs.	Mins.	Hrs.	Mins.	Hrs.	Mins.	Hrs.	Mins.	

M. P. Form 94

ENGINEER'S REQUISITION FOR SUPPLIES.

NOTE.—This form is to be filled out by engineers for all locomotive tools and supplies. It should be made in duplicate by the use of carbon sheets, and the carbon copy retained in the book.

It should be sent to the round-house foreman or master mechanic for approval, and they should see that the engine number and class of service are shown in the spaces provided before the order is sent to the storekeeper for the supplies.

.....SHOPS.....19....

.....

STOREKEEPER.

Deliver to bearer the following articles, viz.:

Quantity	Description of Article.	Weight	Price	Amount	

Charge to Engine No..... In.....Service.

Approved.....

.....ENGINEER

M. P. Form 95.

ENGINEER'S REPORT TO ROUNDHOUSE FOREMAN OF CONDITION OF ENGINES AT END OF EACH TRIP.

NOTE.—Engineers must carefully inspect their engines after each trip, whether needing repairs or not, and report their condition on this form, sending same to the round-house foreman. They will be held responsible for every defect not reported. No attention will be given to verbal reports or reports not signed by the engineer.

When repairs have been made to the engine, and the report signed by the person making the repairs and approved by the round-house forman, it should be forwarded to the master mechanic, to be kept on file in his office.

Condition of Engine No. ..... after careful inspection, on arrival at ....., Time ..... M., Date ..... 19....

Engine is in good condition, with the following exceptions: .....

.....

.....

.....

.....

.....

Condition of Right Injector .....

Condition of Left Injector .....

Condition of Blow-off Cock .....

Safety Valve lifts at ..... lbs.

Safety Valve seats at ..... lbs. ..... Engineer.

(Reverse side of above.)

Repaired at .....

On ..... 19....

The following repairs were made on Engine No. .....

Repairs made by .....
Name of Workman in charge of work.

Approved by .....
Foreman Round-house.

M. P. Form 96

ENGINEER'S REPORT TO MASTER MECHANIC OF PARTICULARS OF STOCK KILLED OR INJURED.

.....Division.

Note.—This report must be made by engineers for all stock killed or injured by locomotives operated by them.

Each question must be answered fully and the report forwarded to the master mechanic, who will in turn forward it to the division superintendent.

1. Date.....19.....Train No.....Passenger or Freight.....

   No. of engine.....Conductor.....Brakeman.....

   Time accident occurred.....M., Daylight or dark.....

2. Number and kind of stock killed or injured.....

3. Place of accident.....

4. Was stock struck on a highway crossing?.....

5. If so, was the proper crossing signal given?.....Was engine bell ringing?.....

6. If accident happened on station grounds, was it between switches or between switch and cattle guard?.....

7. Rate of speed when you first saw stock.....miles per hour.

   Rate of speed when you struck stock.....

8. Did accident happen at point where the track was straight? If so, for what distance before stock was struck?.....

9. Was the alarm whistle sounded for stock?.....

10. If so, at what distance from stock?.....

11. What was the grade? Up or down? And for what distance from point of accident? .....

12. How many cars did you have in train, loaded or empty?.....

13. How far were you from stock when first discovered? .....

14. Give reason why stock was not discovered by you or your fireman sooner?

15. Was stock on track when you first discovered it?.....

16. From which side of the engine did the stock come upon the track?.....

17. State particularly what effort, if any, was made to avoid the accident?.....

REMARKS.

18. Did you notice condition of Company's right of way fences, gates or bars, and give any information you think will be of value to Company, relative to same, and not above stated.....

.....

.....

.....

.....Engineer.

M. P. Form 97

PARTICULARS OF HOURS WORKED BY EACH MAN, RATE OF PAY, WAGES, AND ON WHAT LABOR WAS EXPENDED.

General Time Book of Men Employed at..... In month of..... 19....

	DAYS EMPLOYED																													How Emp'oyed	Details of Work by Hours	Total No. of Hours Worked	Rate	Amount Charg'ble to each Account	Total Amount Wages	NAME	Employe's Check No.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31								
Absent Time																																						
Overtime																																						

M. P. Form 98

REQUISITION FOR AND INVOICE OF MATERIAL.

.....19....

Requisition No.....

Dear Sir:

REQUISITION is hereby made for MATERIAL called for below. Please send without delay to.....at.....

and send invoice to .....at.....

Certified to.....Date.....19..... Signed:.....Date.....19....

Certified to.....Date .....19..... Approved:.....Date .....19....

NOTE.—This blank should be used in ordering material—the quantity "Now on Hand," "Due on Previous Requisitions" and "Additional Quantity Wanted," and "Kind of Material" being entered in the proper places by the person making the requisition.

Upon receipt of this requisition, properly approved, the official upon whom it is drawn will forward the material in accordance with the directions given. Any items which cannot be supplied at once should be drawn off, to be shipped as soon as possible, and the person making the requisition promptly notified of the probable date of shipment.

All items shipped should be invoiced to the proper person, as directed, showing date and initials, and number of car in which shipped and quantity, price and amount in the spaces provided. Before forwarding, this invoice should be copied in the record book of "Material Forwarded."

Before accepting this invoice, the person receiving it should forward it to the person to whom the material was shipped who should compare it with his record of the material received, and in the event of error or omission, or in case there is any variation or defficiency, either in quality or quantity, the subjoined account must be corrected accordingly.

Quantity of Material			KIND OF MATERIAL	MATERIAL SHIPPED		
				DATE..... Car.....		
Now on Hand	Due on Previous Requisitions	Additional Quantity Wanted	IN ORDERING MATERIAL PLEASE KEEP WITHIN SPACE BELOW	Quantity	Price	Amount

M. P. Form 99
DUPLICATE

NOTICE OF MATERIAL ORDERED.

.....19....

..... No.....

.....

The material called for below has been ordered from above named officia l

to be sent to ..... at .....

and to be invoiced to ..... at .....

Note.—This notice will be sent to the person who is to receive the material, for his information and use in checking the material when received.

.....Date,.....19....

Quantity of Material			KIND OF MATERIAL	Material Received			
Now on Hand	Due on Previous Requisitions	Additional Quantity Wanted		Quantity	Date	Car	Invoice Checked

M. P. Form 100
TRIPLICATE

RECORD OF MATERIAL ORDERED.

.....19....

..... No.....

.....

Record of material ordered from above named official to be sent to..... at.....

and to be invoiced to..... at.....

NOTE—This copy will be retained as a record by the person making the Requisition and must be filed in consecutive order according to the number.

.....Date.....19....

QUANTITY OF MATERIAL			KIND OF MATERIAL	INVOICE CHECKED		
Now on Hand	Due on Previous Requisitions	Additional Quantity Wanted		Invoice From	Date of Receipt	Date Checked

ORDERED ON

.....

STOREKEEPER.

.....19....

The following material account of.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

M. P. Form 101

SHOP ORDER FOR MATERIAL.

.....

STOREKEEPER.

.....SHOPS.....19....

Deliver to bearer the following articles, viz :

QUANTITY	DESCRIPTION OF ARTICLE	WEIGHT	PRICE	AMOUNT

And charge the same to.....

.....

FOREMAN.

REPORT OF PIECE WORK PERFORMED BY EACH EMPLOYE.

Check No.....

Shop..... .....Shop,.....19.....

To.....

.....

Please allow.....

occupation..... nature of work .....

.....

number of pieces.....rate per.....

.....

time engaged in above work from.....to.....

.....

Charge to.....

Approved:..... .....

Foreman.

M. P. Form 103.

FORM OF APPLICATION FOR EMPLOYMENT IN SHOP.

NOTE.—Upon this application the applicant may be permitted to enter the service on probation, provided there is need for his services and he has passed a satisfactory examination, by the head of the department, but it must be distinctly understood that before he can enter permanently into the service or be regarded as a regular employe, the written approval of the head of the department must be obtained.

Full name and address of applicant.
.....
.....
.....

Dated at..... 19..

Place of birth.....Date of birth..... 18..Age.....
Nationality.....Married or single.....
What position do you desire?.....
What experience have you had in that line?.....
By whom are you employed at present?.....
No.....Street.....Town or City.....State of.....
In what capacity are you employed at present?.....
Is any one dependent on you for support? If so, give particulars.....
Give particulars and amount of any debt you owe or liability you are under...
Do you drink malt or spirituous liquors?.....
What is the condition of your general health?.....
Are you able-bodied?.....
Is your hearing good?.....
Is your eyesight good?.....
Are you able to distinguish colors?.....
Have you ever been injured? If so, when, where, how and extent of injury...
Name of last school attended.....
Did you graduate.....If not, how long did you attend? .....
State below where and how you have been employed during the last five years making no omission in the record: .

TIME OF SERVICE.				NAME OF EMPLOYER (If the employer was a corporation, give name of such corporation, also name and PRESENT address of official under whom you served.)	Place where Employed	Nature of Employment (How Employed.)	Why did you leave?
FROM		TO					
Mth.	Year	Mth.	Year				

Have you ever been discharged or suspended from any situation? If so, state when, where, and under what conditions?.....
Have you ever been in the employ of this Company before? If so, state when, where, in what capacity, and cause of leaving.....
Give below the name, address and occupation of your parents and other relatives. If any are deceased, give other nearest relatives:

NAME.	OCCUPATION.	ADDRESS.
Father.....	.....	.....
Mother.....	.....	.....
NEAREST MALE RELATIVE:		
On Father's side.....	.....	.....
On Mother's side	.....	.....

Are any of your relatives in the employ of this Company? If so, state who they are, and in what capacity employed.....
Will you faithfully perform such duties as may be legally required of you by your superiors?.....

In consideration of my employment by said company, I agree that whenever I shall sustain any personal injury while in the service of said company I will allow its surgeon and any medical examiners it may select to examine my person and body as often as the company may deem necessary in respect to the alleged injury, and I hereby waive all objections to such surgeons or medical examiners testifying whenever called upon by the company, and I further agree that my refusal to allow any such examination to be made or testimony to be given shall be a bar to the institution or prosecution of any action on account of such injury; and any action pending at the time of such refusal shall at once abate in consequence thereof.

In further consideration of such employment I agree that if, while in the service of said company, I sustain any personal injury for which I shall or may make claim against the company for damages, I will, within thirty days after receiving such injury, give notice in writing of such claim to the General Claim Agent of said company; which notice shall state the time, place, manner and cause of my being injured and the nature and extent of my injuries, and the claim made therefor, to the end that such claim may be fully, fairly and promptly investigated; and my failure to give written notice of such claim in the manner and within the time aforesaid, shall be a bar to the institution of any suit on account of such injuries.

I certify that my answers to the above questions are true, and agree that they shall be the basis of my employment.

Signature of Applicant.....

(All applications for employment in this Department must be made on this blank in duplicate, and when party enters the service of this company the employing officer will send both copies to the head of the department.)

DAILY DISTRIBUTION OF LABOR FOR MANUFACTURED MATERIAL WORK.

M. P. Form 104

.....19....

CHECK NO.....RATE..... NAME.....

OCCUPATION.....

Hours Worked	Pieces Completed	Order No. Worked On	Description of Work	Machine Number

.....

FOREMAN

To be used only for material manufactured at shops.

M. P. Form 105

DISTRIBUTION BLANK FOR MATERIAL USED.

.....SHOP.

Folio of Distribution Book.....

GENERAL DISTRIBUTION OF MATERIAL BOOK, for the month of.....19

Charged to.....

M. P. Form 106

DISTRIBUTION BLANK FOR LABOR PERFORMED.

.....SHOP.

Folio of Distribution Book.....

GENERAL DISTRIBUTION OF LABOR BOOK, for the month of.....19

Charged to.....

NAME	KIND OF SERVICE	Folio Time Book	Time Worked	RATE	Detailed Amount		Total Amount	

M. P. Form 107

MONTHLY STATEMENT OF THE TONNAGE HAUL OF ENGINEERS AND AVERAGE NUMBER OF TONS HAULED PER TRAIN.

For month of.....19.....

NAME OF ENGINEER	Engine Number	Engine Mileage	NO. TONS HAULED ONE MILE	Average No. of Tons hauled per Train

NOTE:—The train reports of conductors show the engine mileage and train tonnage, and from these reports this exhibit is compiled. It is a summarization of an account kept with each engineer and shows his engine mileage and gross train ton-mileage. The information is of peculiar value in directions that need not be explained, to those concerned in the movement of equipment and traffic.

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Locomotive, description of.....I 13

means that the item will be found on page 13 of Book I.

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